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PRINCIPLES

OF

AGRICULTURE

BY

WM. T. LAWRENCE

TEACHER OF THE PRINCIPLES OF AGRICULTURE
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NOTE.

In this book the words in thick type are not necessarily to be emphasised like those in italics; but, by being read *alone* at the end of each lesson, to form a rough summary of its contents. Thus in Lesson IV. they read:

(1) Air—nitrogen, oxygen, carbonic acid.
(2) Carbonic acid enables rain-water to dissolve surface of a rock.
(3) Rain-water dissolves carbonate of lime.
(4) Rain-water, [with] carbonic acid, dissolves from rocks potash and soda.
(5) Running-water wears away rock.

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PRINCIPLES OF AGRICULTURE.

PART I.

LESSON I.—INTRODUCTION.

1. The title of this book tells you that it is all about 'Agriculture.' Now the word **Agriculture means field tillage**; and it comprises all the different kinds of field-work that a farmer has to do. In talking to you about this field culture, I must first describe to you the *materials* with which the farmer works. If I were to ask you, 'What are the materials with which the carpenter works?' you would at once reply, 'Wood, nails, screws, and glue.' And you would be able to tell me quite as readily, that out of these he can produce doors, window-sashes, desks, and hundreds of other things. Now the farmer has to produce food for man and beast; and the materials which he uses for this purpose are the soil, seed, and manure. Besides these, water, air, and sunshine are necessary; but these are not under his control as the others are.

2. When the carpenter begins to make a door, he is able to complete it thoroughly; but the farmer can only begin his work, for when he has prepared his ground and sown the seed, he must depend upon the great God of nature to make the seed grow, and produce the fruit, ripe for use.

3. Again, for some purposes the carpenter uses deal, for others oak, for others elm, and so on; and he must understand these different kinds of wood, so as to use them in their proper places. Now there are many different kinds of soils, and some will produce certain crops much better than they will others; so the farmer must understand the different kinds of soils, and for what crops they are best suited, just as the carpenter must understand the different kinds of wood, and for what purposes

they are most suitable. I am going to describe to you then, in this book, the various soils and manures, and how the farmer uses them in order to produce the largest crops.

LESSON II.—WHAT ARE SOILS?

4. First of all we will talk about the soil—that of which our gardens and fields consist, and which you sometimes call dirt, earth, or mould. When you have been digging in the garden, have you ever said to yourself: 'I wonder what this soil is made of'? Well, what is it made of? I fancy I hear one boy say, of decayed roots, and stems of plants of various kinds; and decayed manure which has been dug in, year after year. And this is right as far as it goes, for these things do help to make the soil. And in some places, as in the middle of Russia and in many parts of Ireland, there are soils composed almost entirely of decayed vegetable matter. But generally speaking, the great bulk of the soil would have been there, if none of these things had been added.

5. If you take some dry soil in your hand, and crumble it as fine as you can, you will perhaps find that some of it is in the condition of a very fine powder, some of it in the form of tiny grains of sand, and some in the form of little stones; and if you look on the ground, you may also see a large number of stones of various sizes scattered about. It may be that even the powder feels gritty and has a glistening appearance, which shows that it is only very fine sand.

6. But perhaps it is nearly *all* in a powdery condition, soft to the touch instead of gritty, and when moistened and squeezed, holds together and becomes plastic or soapy, so that it may be moulded into any shape. Such a soil would be called clay; and you know, bricks and all kinds of earthenware are made from it.

7. Now you can easily see that the sandy soil is composed of little else than stones, though they may be as small as dust-grains. But what are stones? They are bits of rock. The dust-grains, the sand on the sea-shore, the larger pebbles, the stones of which houses are built, are all pieces of rock. And even the

clay, strange as you may think it, is only a certain kind of rock, which has softened down till it feels like putty.

8. But you will say: 'How was the greater part of the soil in the world made from the rocks?' Or: 'Where are the rocks from which the soil was made?' And: 'If they are a long way off, how did the soil get to its present situation?' These are very interesting questions, and I will try to answer them all by degrees.

LESSON III.—WHAT FROST DOES TO ROCKS.

9. **Frost**, with the help of water, is the great **breaker-up of rocks**. And it does this work in the same way as it bursts water-pipes, and vessels in which water is kept in the winter. Frost is a giant that can as easily break rocks and iron in pieces as you can a stick.

10. As a general rule, the colder anything becomes, the smaller it gets; just as the hot iron rim or tire, which the wheelwright puts on the wheel, immediately shrinks when he throws the cold water on it. It is large enough to go on easily when hot; but after it is cooled, it fits so tightly, that every joint in the wheel is pulled quite closely together. In like manner water gets less in bulk the colder it gets, till it reaches a point of coldness a few degrees above freezing; when, strange to say, the colder it *then* gets, the more it *increases* in bulk, till by the time it becomes ice, it is so much larger, that six pints of water would, when changed into ice, occupy the space of about seven pints. Now, if it has not the room to swell out in this way, it will burst whatever confines it, and so make room. We do not generally find out the cracks which it makes by thus expanding until the ice thaws; for while it is in the solid state, it holds the pieces together.

11. In the winter-time many of the cracks and crevices in the rocks get filled with water, and when this freezes, it swells out, and by degrees splits the rocks into large pieces. Besides this, water, either as rain, fog, mist, or snow, soaks a little way into the surface of the rock, particularly if it is not a very hard kind, and when it freezes, pushes the tiny particles of stone apart, and so causes the surface to crumble away.

12. I dare say you have noticed how the surfaces of stones, in the walls of old buildings, have been worn away by this same means; and this is what is meant in the decay of the stones by the '*weathering*' of winter. Clayey ground is often broken up into great rough clods in the autumn, for the frost of the following winter to crumble it for seed-sowing in the spring; and it does it by the method I have described, much better than man can do it with all his implements. And this is the way in which soils are first formed on the surfaces of rocks, upon which mosses and such-like tiny vegetables grow. These again decay, and so help to improve the new soil for yet higher forms of vegetable life.

LESSON IV.—WHAT WATER AND AIR DO TO ROCKS.

13. Before I can tell you what water and air do to the rocks, I must tell you what air is. You all know it is everywhere around and about us, and forms the atmosphere, or covering of air which surrounds the great ball on which we live; that we draw some of it into our bodies each time we breathe, and that we cannot live without it. You also probably know that wind is really air in motion, and as such we can feel its pressure, and hear its noise. But this is not saying *what* air is. Well, air is a mixture of certain gases, just as the coal-gas which lights up the houses and streets of our towns is a mixture of certain *other* gases.

14. **Air** consists mostly of a gas named **nitrogen**; about a quarter as much of another gas called **oxygen**; and a very small part of it indeed also consists of a third gas called **carbonic acid**. But as the nitrogen does not interfere with rocks at all, and the oxygen only to a very small extent, I need only tell you about the carbonic acid gas.

15. As rain falls through the air, some of the **carbonic acid** mixes with it, and this enables the **rain-water to dissolve** some of the **surface of a rock** just as it would, without the carbonic acid, dissolve sugar. But there are some kinds of rocks which the rain-water can dissolve much more easily than others, and these are the rocks which contain the lime that is used to make mortar for building. Limestone, chalk, and marble are of this

kind. These rocks consist chiefly of lime and carbonic acid, and for this reason are said to be made of carbonate of lime. When they are burned in the limekilns, the heat drives the carbonic acid gas off into the air, and so the lime—quicklime as it is now called—only is left. It is this solvent power of rain and mist when they contain carbonic acid which causes marble tombstones to become worn and rough. And this is how the great limestone caves in different parts of the world have been formed.

16. Some of the **rain-water dissolves** so much of this **carbonate of lime** from the rocks, that when we get it again from our wells or springs, and boil it, it leaves a coating, on the inside of the tea-kettle, of carbonate of lime, which often comes off in thin flakes, as you may have seen. And in like manner, as this water is warmed or evaporated—that is, turned into steam —by the sun on the surface of the ground, it leaves some of the carbonate of lime behind on the soil.

17. **Rain-water**, by the aid of the **carbonic acid**, also **dissolves from** the surface of **rocks** some of the **potash** and **soda** which they contain; this leaves the particles of the rocky surface in a less firm condition, and more porous; consequently moisture is easily retained, which with the frost readily crumbles it into powder. So you see now how water which contains some of the carbonic acid of the air, can dissolve all rocks away, and especially those which contain much lime.

18. **Running-water** slowly wears away the **rock** over which it travels, and the more particles of rock and soil it carries with it, the more quickly can it grind away the stony surface below. This, as you will see, is a power which streams possess quite independent of the carbonic acid of the air.

LESSON V.—REMOVED SOILS.

19. **Soil** sometimes remains where it is formed, but in many cases a great deal of it is **carried away by rivers**, and either **laid down again in other places**, or carried into the sea. Those soils which are still in the places where they were first formed may

be called **stationary soils**—that is, standing-still soils—and they now cover the rocks of which they were once a part.

The white chalk soils which cover the chalk hills of England, and a great deal of the clay and other soils which are to be found in the less hilly and central parts of the country, are soils of this kind, and consist of the same material as the underlying rocks from which they were made, though they are often a mixture of the different kinds of rocks which adjoin each other.

20. Soils which have been brought away from their native rocks, and laid down in other places, are called **transported soils**—that is, soils which have been carried across. We will just notice how this removal takes place.

The rain which falls on the mountains and hills, washes the fine soil from the surface of the rocks of which it was made, and runs down the sides in thousands of little streamlets; these join together and form swift torrents, which are able to carry with them bigger pieces of the rock; these again join together later on, to form a muddy river. Soon the larger and heavier bits of rock fall to the bottom; and the coarser grains, though carried farther on, sink as the river reaches the plains below, and so the water gets clearer and clearer, till only the very smallest particles of soil are carried by it to its mouth.

21. As the river pursues its course, feeders flow into it on each side, and bring with them soils which they have washed from rocks of perhaps quite a different kind from that from which the river itself started; and thus the soil carried to the mouth would not only be very fine, but very likely of a mixed character.

22. Very slowly, but each moment of each day and night for hundreds of years, some of this soil is deposited at the mouths of rivers, and large flat tracts of rich clay of a mixed character are gradually formed. These are called **alluvial** or mud soils.

From what I have said, you would expect to find these alluvial soils along the flat parts of a river's course, and especially at its mouth; and this is exactly the case. On each side of the Humber, and round the Wash, are extensive alluvial districts; and if you look at a map of the world,

you will notice that the land quite juts out into the sea at the mouths of the river Mississippi in North America, Po in Italy, and many others, from the alluvial soils which these rivers deposit at their mouths.

23. I told you that much of the fine soil is carried into the sea; there it gradually sinks to the bottom. But this is not always lost; for in some parts of the coast the mud is thrown up by the waves and tide, or the sea ceases to cover it, and so we have alluvial soils formed by the sea. Land near the south-east coast of Kent, and coast of Somerset, has been formed in this manner.

LESSON VI.—OTHER SOILS UNLIKE THE UNDERLYING ROCK—LAVA SOILS.

24. There are two other kinds of soils which I must describe to you, that have not, like the alluvial soils, been transported or carried across the surface of the country from one place to another; nor are they formed from the great mass of rock beneath, like the stationary soils, but lie upon it. They are lava and peat soils. We will first speak of lava soils.

25. You remember learning in your geography lessons that there are certain kinds of mountains that have been thrown or pressed up by the fire and heat that are raging beneath the surface of our earth, and that some of these have large openings called *craters* at their tops, through which they throw up from time to time showers of *ashes* and streams of *lava.*

These mountains, as you know, are named volcanoes. The molten lava flows down their sides, sometimes in such large quantities as to fill the valleys, and cover the plains below for many miles. In South America, Italy, and many other parts of the world, this is going on *now.* But there are many other parts where old volcanoes, which no longer throw out their fiery substances, are still to be found with their fields of lava all around. Such *extinct* volcanoes, as they are called, extend across the middle of Scotland, and occur in the north of England, in North-west Wales, and in the north-east of Ireland. And from the lava,

which they poured out thousands of years ago, very fertile clay soils have been formed.

26. In order to explain to you how this takes place, I must first tell you that lava is simply molten rock—that is, rock which has been melted by the fierce heat of the fire within the earth. As it flows down the sides of the mountain, and over the surface of the ground below, it gradually gets cold, and once more hardens into rock ; but not such compact rock as before, for it is full of gas, air, or steam bubble-holes ; and, in shrinking as it cools, becomes cracked in all directions. In this state it is easily acted upon by the rain and frost of winter, and is thus slowly crumbled into a fertile clay, in the manner I have described to you in one of our former lessons.

LESSON VII.—PEAT SOILS.

27. The other overlying soil which I said I would describe to you is peat. You may remember that I told you in Lesson IV. that in some parts of Ireland and Russia, and many other countries, the soil consists almost entirely of decayed plants ; this soil is called peat. Large tracts of peat are found in Ireland, Scotland, England, Russia, Germany, France, and in all the northern countries of Europe. In Ireland they are called **bogs**, and in Scotland and England, **peat-mosses**. There are nearly three millions of acres of peat in Ireland—that is, one-seventh part of the whole country.

28. In some places, bogs or peat-mosses extend over very large, flat, low-lying plains, and look like either wide brown moors or green marshes. In others they are met with in smaller patches, in hollows of hilly districts, and are then of a darker colour. Sometimes the peat-bed is only about ten feet thick ; while at others it reaches a depth of forty feet. In some places it is so firm and dry, that it can be ploughed and tilled, and will produce good crops of turnips, potatoes, barley, and oats. In other places it is just firm enough for you to walk on by picking your way between the wet places, but you can feel it shake under you as you walk along. When in this condition, it is often covered with coarse grass and heather. But there are

yet other places where it is so soft and wet, that if you were to venture on it, you would sink lower and lower into a kind of dark mud, until you were completely buried and lost.

29. In the districts where peat is found, it mostly forms the chief kind of *fuel*—that is, the people burn it in their houses, to warm them, and to cook their food by. In the summer-time men cut it out with spades, and lay it in heaps to dry in the sun. It takes some time to get quite dry, as it contains a large quantity of water. The men and carts often have to stand on boards, that they may not sink into it.

30. If you have never *seen* a peat-moss, you will *now* have some idea of its appearance from what I have just told you ; but it still remains for me to explain to you how it is formed.

Wherever there is a peat-moss, there must have been first of all either a marsh or shallow lake, for standing-water is the great cause of the production of peat, as I shall soon show you.

But marshes are formed on low-lying levels, where water collects from higher ground, and where the soil is of a clayey nature, and will not let the water soak through. Lakes are also formed in hollow places, whence the water, which collects from the surrounding hills, cannot easily flow away. Hence these are the places where peat is formed.

31. Very soon water-plants of different kinds begin to grow thickly all over the marsh, and all round the shallow edges of the lake ; and mud gathers about their stems. As these die, others spring up, and especially a kind of moss, which sucks up water like a sponge, and throws out new shoots as the old moss-plant rots away. Year after year, fresh moss-plants grow on the top, and the old ones get pressed down tighter and tighter as they decay, till at last the place of the water in the marsh is, in a great measure, taken up by this decayed moss or peat.

At last, larger kinds of water-grasses and plants grow on the now firmer surface, and as they decay each year, a still firmer surface is formed. Such is the story of peat formation in what was once a marsh.

32. In the case of a shallow lake, the moss and other plant growth begins, as I have said, on the shallower margin or border, and gradually extends inwards till the whole of the lake is filled up.

In some places this peat formation may actually be seen going on now, much in the same way as I have described. On the outside of the lake you may find the peat firm; as you go towards the middle, it becomes softer and wetter; and in the middle there is water still—the only remaining part of the former lake yet to be filled up by vegetable growth and decay.

At the bottoms of these peat-mosses, the shells of the fresh-water shell-fish, which lived in them while yet they were lakes, are still to be found; and the remains of old canoes have also been found, which were at one time used to carry their owners across these very lakes.

33. The peat at the top is a mass of fibre—that is, consists of a quantity of thread-like material thickly matted together; while that at the bottom, through having decayed more, and been pressed tighter by the weight above, has lost this fibrous character; it is darker and more solid, and when dried, heavier.

Peat is not found in hot countries, because the great heat dries up the marshy places before the peat can be formed; for, as I have already shown you, the plant growth must take place in water, and the decay under water for very many years together before peat can be produced.

LESSON VIII.—HUMUS.

34. I told you in Lesson IV. that *all* soils contain *some* vegetable matter; and this matter is very much like peat—dark brown, soft to the touch, and generally damp. It is called *Humus*. The fallen leaves of trees in autumn are often gathered, placed in heaps, and left to decay. In course of time they rot, and become changed into a dark brown, soft, moist mould, called **leaf-mould**. This is the substance—**Humus**—that I have just mentioned. As leaf-mould it is much used in the cultivation of ferns and flowers.

Humus is formed in *un*cultivated soils by the decay of *all* the parts of the wild plants which grow on them; and in cultivated soils by the decay of those parts of the plants that are not required for food, such as the roots and stubble of corn and clover crops. So, of course, the more fertile the soil, and

the greater the crops grown, the larger will be the quantity of humus formed.

The rich brown colour of most soils is due to the humus which they contain; and because the richest soils generally contain most humus, some people have thought that it is the cause of the richness; but from what I have just told you, you can see that they are mistaken; for it is the richness that is the cause of the large quantity of humus.

35. Still, humus does improve a soil in many ways. Being somewhat spongy in its nature, it is able to suck up and retain moisture; and by so doing, helps to keep a soil cool and moist in hot, dry weather. It also helps to make a sandy soil less gritty, and better able to keep manure from being washed through it; and a clayey soil less soapy. But above all, it forms food for plants when it has completely decayed. I will give you a well-known instance of this:

36. Clover has very long and very many roots, and they go down a great depth into the soil. As they decay, they form a valuable manure or food for the next crop that is planted in the same ground; especially if it be a crop with deep roots like the clover. Wheat is of this character; and so it has become the custom to sow wheat after clover, as it has been found in practice, that wheat always thrives well after it. And the reason is, that its deep roots find a good supply of a certain kind of food, which it much requires, through the decay of the clover roots, or, as we might say, from the complete decay of the humus, which is formed from the clover roots.

LESSON IX.—THE NATURAL KINGDOMS.

37. That portion of a soil which is got from the rock is called the *mineral* part, and that which is produced by vegetable decay —the humus—the *organic* part. And as these are terms which are frequently used in speaking on agricultural matters, I want you thoroughly to understand what they mean.

38. There are said to be three kingdoms in nature—the animal, vegetable, and mineral.

In the *animal* kingdom are included all kinds of living

creatures, whether they be birds, beasts, fishes, reptiles, or insects; as well as all things that are produced from any portion of their bodies. So you see, the wool off the sheep's back, the leather made from animals' skins, and the silk spun by the silk-worm from its own body, are all animal productions, and therefore belong to the animal kingdom.

39. All kinds of plants, from the largest forest tree to the smallest moss, belong to the *vegetable* kingdom; and all things obtained from plants, whether as food or clothing, are also included in it. Now, as you know, animals make manure to feed plants, and plants supply food for animals; so the animal and vegetable kingdoms help to make and support each other.

40. Everything that does not belong to one or other of these two kingdoms must be classed in the *mineral* kingdom. Rocks, stones, metals, clay, chalk, salt, and coal are all called minerals; and although this kingdom is very unlike the other two, yet it is closely related to them; for as you know, the rocks form soils to feed plants; and—as perhaps you do not know—plants and animals have made rocks. Coal was formed many ages ago from forests of giant ferns. The chalk rocks consist of nothing more than millions upon millions of sea-shells, firmly pressed together, and are therefore really animal remains. And the beautiful coral rocks, pieces of which you may have seen, were made by millions of little insects, called coral-worms.

41. In our daily *food*, the bread belongs to the vegetable kingdom, the milk or meat to the animal, and the salt to the mineral. In our *clothing*, the straw-hat, and the calico shirt from the cotton-plant, are of vegetable production; the woollen-cloth jacket and trousers, and leather boots, of animal; and the iron nails in the boots, and metal buttons on the other parts of our dress, of mineral.

42. An animal is very much unlike a vegetable in some things, but very much like it in others. Of course you know a vegetable cannot walk about, or see, or hear, like an animal; and having no mind, it cannot think, or understand, or do as it wishes, as an animal can. But they both have *life*, only of a widely different kind; they both live and *grow by taking in food;* and they both have certain parts of a particular form, whose special work it is to change the food into a real portion

of the living animal or plant; these parts are called the organs of the animal or plant. The roots, stem, leaves, blossoms, and fruit are *plant-organs;* and the lungs—lights, as butchers call them—liver, heart, kidneys, and blood-vessels are a few of the many *animal organs.*

43. Minerals have no kind of life whatever, and therefore no organs, as you are well aware. And now that I have told you thus much about these three kingdoms, you can perhaps see, that the reason why all animal and vegetable substances are called organic, is because they are portions of things which consist of organs; and all other substances, mineral, because they belong to the mineral kingdom.

LESSON X.—LOOKING BACK.

44. In all the previous lessons, we have been considering how soils are formed *naturally*—that is, by those means which God has appointed, and without man's help at all. And we have seen that all except peaty soils are, at first, merely tiny particles of rock, which are *crumbled* from its surface by the action of *water* and *frost*, or *dissolved* from it by *water* and *air* together.

45. And in nearly all soils, there is still a large store of rock yet to be acted on year after year for ages to come by the water, frost, and air. I mean the large store of stones, some smaller than pins' heads, and others as large as hens' eggs, which are present in all but peaty soils. And being small and scattered, they are in a more suitable condition to be acted upon, and made into useful soil, than rock in its massive state.

People often look upon stones as useless, but such is not the case; for the tiny chips soon decay and partly dissolve in water, and so form a part of the real soil, which can be sucked up by the roots of plants to feed them and make them grow. And even the large stones must in course of time, though very slowly, decay, and also form a most useful part of the soil.

46. Alluvial soils generally contain those smooth rounded stones which we call pebbles; they have been carried from their native rocks, by rivers or glaciers, and laid down in their present positions. They were, first of all, like all other stones,

rough and cornered, but by being constantly knocked and ground against each other by the force of the water, they have become changed into smooth pebbles.

Hard flint-stones are found in the more crumbly or *upper* chalk, as it is named; and I have noticed fields on the Chiltern Hills so thickly covered with them, that no soil could be seen. The farmers say that this covering of stones keeps the soil beneath from being dried up as quickly as it otherwise would be by the summer sun.

Other soils, such as those formed from the limestone rocks, contain stones which are pieces of the parent rock beneath. Many clay soils are made much more open and more crumbly by the stones they contain, and are therefore more healthy for plant-growth, and easier to till. So you see, stones are not such worthless things in the soil as people are sometimes apt to think.

47. We have also learned that alluvial, lava, and peat soils are *overlying* soils, that have been laid upon the natural rocks or soils of the districts where they occur, by the river and sea, or the volcano, or by vegetable growth and decay. And I think you will say that I have kept my promise, and answered pretty fully the questions proposed in paragraph 8.

LESSON XI.—PROPERTIES OF SOILS—I.

48. By the term 'properties of soils' is meant, the various powers which soils possess. For instance, it is the property of soils to supply plants with food. Soils also have the power to hold moisture. But they have other wonderful properties besides these, that I should like you to know a little about. All soils have not the same properties, because they do not all consist of the same proportions of sand, stones, humus, lime, and clay, and are not all formed from the same kinds of rock.

49. Plants cannot feed on solid food, as animals can; they live entirely on liquids, which they suck up through the tiny hairs which cover the young thread-like roots; and these hairs are so fine that you cannot see them without the aid of a microscope—a wonderful kind of spyglass which makes things

look hundreds of times bigger than they really are. So you can quite understand that no solid matter can be taken in by such very tiny mouths.

Now this teaches us two great truths about plant-food: firstly, that it must be soluble in water, as sugar and salt are; and secondly, that there must be water present to dissolve it, before the plants can take it in.

You have already learned that rain-water, by the help of the carbonic acid gas which it gets from the air, is able to dissolve mineral substances that pure water cannot. It has also been discovered that some mineral substances can be very slowly dissolved by the juices of the root-hairs. And so, whatever substances in the soil can be dissolved by rain-water, or the juice of root-hairs, can be carried into the plant; and whatever substance will not thus dissolve, cannot be carried into it; and therefore the **real plant-food in the soil is the soluble matter.**

It is only a very small part indeed of even a good soil that is soluble plant-food; but yet the other part has its use, for it has to hold the plant firmly in the ground, as well as to keep the water and soluble soil ready for the plant to feed upon; and in course of time some of *it* also will dissolve and become plant-food.

50. If you were to take three flower-pots, and fill the first with marbles, the second with sand, and the third with fine soft powdered earth, and then pour water into them, you would find that the water would run through the pot with marbles, almost as soon as you poured it in; but that it would take a little longer to run through the one containing sand, and still longer to soak through the third. This shows us that the finer the particles of the substance, the longer will it hold the water; and why? Because small particles lie so much closer together than large ones, that the spaces between them are too small to let the water run through quickly. Now, clay consists of very fine particles—finer particles than any other kind of soil—therefore **it is able to hold water** for the use of plants better than any other soil. But the fine particles of clay may be pressed together so closely when damp, that no water is able to get through at all; this is not good for plants. A field with an under-soil of clay in this closely pressed condition would not

allow the water to pass downwards, but would cause the top to remain soaked with stale water, which is poison to plants. Such land is very cold, and also very unhealthy both for people and animals to live on or near.

LESSON XII.—PROPERTIES OF SOILS—II.

51. I said soils had other properties besides the power of holding moisture, and supplying plants with dissolved food. We will talk about two of the most important of them in this lesson.

We took three flower-pots for our experiments in last lesson; we will take two barrels with holes in their bottoms instead, this time. Let us set them up, so that we may be able to catch the water which comes through; and we will fill the one with sand, and the other with powdered clay soil shaken down well. We will next take some of the dark-brown or nearly black nasty-smelling water that runs from a manure heap, and pour part of it into each barrel. We shall find that it comes through the sand first, but is not so dark in colour as it was when poured in. The part that was poured on the clay soil takes much longer to soak through, but when at length it does find its way to the bottom of the barrel, it is quite clear and without smell. What has caused this change?

52. The manure which was in the water, and gave to it its dark colour and nasty smell, in going very slowly through the soil, has gradually stuck to the fine soft particles, till at last nothing but the clear water is left to reach the bottom. Here, then, is another property of the soil, especially of a clay soil—that it **can hold manure**, even **soluble plant-food**, for the use of crops.

Charcoal — especially charcoal made from animal remains, such as burnt leather—has this power in a still more wonderful degree; and for this reason, water-filters, through which many people let their drinking-water pass before using, are partly filled with it. The charcoal keeps back all that is unpleasant and bad in the water, and thus makes it pure and wholesome to drink.

53. There is yet another curious property that soils possess in common with many other substances ; it is the power to cause moisture to spread through its particles in all directions, even upwards. Water sinks *downwards* by its own weight, but will also spread *upwards* by a power called '**capillary attraction**,' which means, 'the drawing power of *hair*-like tubes.' If you cannot remember this hard name, you must not forget its meaning—namely, that **soil has the power to draw moisture upwards.**

54. You have all seen this power at work over and over again. Directly the end of the cotton-wick of a lamp is put into the oil, the oil begins to spread up the wick, and continues to do so until it reaches the top ; and as fast as the oil burns away at the top, more comes up from below, till it is all used. Or again, persons often place flower-pots in saucers, and instead of watering the flowers which are in the pots at the top, they pour a little water into the saucers ; and very soon this is drawn or sucked up, as you would say, by the mould in the pot. If you had made a large blot on your copy-book, how would you dry it ? You would not lay the blotting-paper on it flat at once, and spread the blot larger ; but just let the tip of it touch the ink, and suck it up.

55. It has been noticed that if fine sand be put into one long glass-tube, and powdered clay into another, and the ends placed in water, the water will quickly rise to a height of nearly two feet in the sand-tube, and more slowly to a height of three feet in the clay-tube ; but if coarse bits of clay or sand are used, the water will scarcely rise a foot. And so we learn that the smaller the spaces between the particles of soil, the higher will moisture rise ; and that **clayey soil** not only has the power of keeping water from running downwards quickly, but also, when dry, **can draw it up from below to a greater height** than sandy soils.

LESSON XIII.—CLASSES OF SOILS.

56. You know what the classes of a school are—namely, the groups of children into which it is divided for instruction. All the children in the *same* class are taught the same things together, because they are all nearly alike in scholarship. In a

similar manner, soils may be divided into classes; those that are alike being placed in the same class.

The best scholars in a school form the first class; the next best, the second; and those that are only just beginning to learn, the last class. In the same way, the best soils—those that are most fruitful, that is, grow the largest crops—form the *good or fertile* class; the soils that will only produce small crops, form the *poor* class; while those that are fairly fruitful, are called *intermediate* soils, which means, that they form a class between the good and the poor. If a soil is unable to grow any crops at all, it is termed *barren or sterile;* the soils of the deserts belong to this class. So you see, that if soils are classified or grouped according to their fruitfulness, we get—(1) **Fertile or good soils**; (2) **Intermediate soils**; (3) **Poor soils**; and (4) **Barren or sterile soils.**

57. But suppose the boys of a school were going to be drilled, instead of being taught some school subject; they might then be classified according to size, instead of scholarship; and we could have the tall class, the middle-height class, and the short class. And so with soils, there are other ways of classifying them besides the one I have just mentioned.

We have already said a good deal about **sandy soils** and **clay soils**; and you have seen that they are very much unlike each other. But between sand and clay are several other classes. For instance: soils that are made up of about equal shares of sand and clay, are called **loams**; if a soil contain much more clay than sand, it would be called a **clay loam**; and if more sand than clay, a **sandy loam.** But to these five classes are added three others, in order that every soil may find a place in some one class or other. They are—(1) **Marls**, which are really clays, loams, or sandy soils, of which much less than a quarter consists of lime; (2) **Calcareous soils**, which are formed from the limestone or chalk rocks that yield quicklime when heated in a kiln; and (3) **Peaty or Vegetable soils**, which you have learned all about in a former lesson.

58. And this is the grouping generally used, because upon it depends, in a great measure, the kind of crops that should be grown, the plan of tilling to be followed, and the kind of stock that should be kept on any particular soil, or in other words, the system of farming which should be employed.

LESSON XIV.—FERTILE AND BARREN SOILS.

59. From what I told you in our last lesson, you know that a fertile soil is fruitful, and a barren one unfruitful; but perhaps you do not know the exact causes of this fruitfulness or barrenness. They are many. You have learned that plants grow by taking in food, just as animals do. This food *must* consist of certain substances; and if any one of them is quite absent from the soil, vegetable growth ceases. I cannot *now* tell you much about these substances, though I hope to do so in a later lesson; but I will just tell you now, that by far the largest part of the food of all plants consists of what their leaves suck in from the Air around, and Water, which is absorbed by their roots. But besides these, they *must* be supplied from the soil with Nitrogen, which forms so large a part of the atmosphere, but which plants get chiefly *from the decaying organic matter* of the soil; Phosphoric Acid and Lime—substances of which bones are mainly composed; Potash—a substance something like soda; with a few other mineral substances. And these must all be in a form that can be easily dissolved, so that the tiny roots may be able to suck them up.

60. If a soil is without any one of these substances, it is so barren that it will not grow a blade of grass. And if they are present, but not in a soluble form, then too, the soil is equally barren; for although the substances are present, the plants cannot absorb them in their insoluble state. And yet it is necessary that a fertile soil should contain a quantity of even this *insoluble* matter, because, little by little, it becomes changed into *soluble* plant-food—mainly by the action of the carbonic acid in the water of the soil—and so helps to *keep* the soil fertile.

61. There are some things that are poisonous to plants, and if present in a soil in sufficient quantity, will make it unfruitful or perhaps quite barren. So you see a soil may be rendered poor, not only by having an insufficient supply of one or more of the substances which plants need for their growth, but also by containing other substances which destroy plant-life altogether. *Salt* is one of those substances which renders many soils barren

when present to a large extent. *Iron* will also make a soil unfruitful when present in a certain form in large quantities. And *stagnant water*, and *certain organic acids* which are produced by the decay of vegetables in wet or marshy places, will make a soil sour and unfit for the growth of common farm crops.

62. No soil can be called good that is not well drained—that is, through which water cannot pass gradually but easily downwards. For as I have already told you, stale water is very hurtful to plant-life; and if all the little pores or holes in the soil are filled with stale water, there is no place for the fresh rain-water with its carbonic acid, and so it is obliged to run off the surface. Neither is there room for the air to enter, to help the growth of seeds, and to improve the soil. The land also is kept colder than it would otherwise be, and so the crops grow and ripen but slowly.

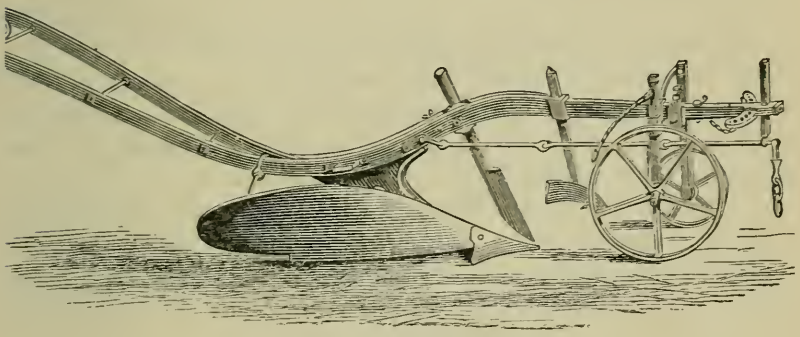
63. And yet a soil should *not allow the water to pass through it too quickly*, otherwise it gets parched and dry, and lets the soluble plant-food be washed through with the rain, out of the reach of the roots of the crops. To prevent these mishaps, *the soil should either contain a good share of soft clay particles, or humus*, both of which suck up moisture and retain it for a long time.

64. Then again in texture, a soil should be firm enough to hold plants tightly in the ground, and not to be blown away as dust, with strong winds. At the same time it should be friable, that is, crumbly enough to allow the roots to spread easily in all directions, and also to allow the air, warmth, and rain to get into it. A loamy soil is of this character; and good cultivation, such as ploughing, grubbing, harrowing, and rolling at the right time, tends to produce this healthy condition of texture.

65. There is yet one other cause that may prevent a soil being fruitful, and that is, *an unsuitable climate* for the growth of plants. Such is the case in the deserts, and in the countries in the cold north. In the former they have *no rain*, and in the latter, *not enough of the sun's warmth.*

LESSON XV.—CULTIVATION—A MEANS OF ENRICHING LAND.

66. You may have often seen the ploughman at work in the fields, steadily going backwards and forwards from one end to the other, and turning over the soil in long straight furrows. And if you were asked, 'Why does he so cut it up and turn it over?' you would probably say, 'For the same reason that people dig their gardens, namely, to make the ground soft, and so prepare it for seed-sowing, and for the growth of the crop



Ransomes' Wheel-plough.

afterwards.' And this answer is quite right as far as it goes. But *how* does this in any way prepare the ground to receive the seed, and improve it for the healthy growth of a crop? I will try to answer this question for you.

67. You know, from what I have told you of the formation of soils from rocks, that rain-water by the help of the carbonic acid gas which it has absorbed from the air, actually dissolves out of the rock some of the materials of which it is composed. And this action will go on much more quickly among the countless number of tiny rocky particles of a ready-made soil, than on the surface of a mass of rock. I have also told you in a former lesson that the roots of plants can only feed on those substances in the soil which are soluble in rain-water and in the juice of root-hairs.

68. Now, *when land has been thoroughly broken up by the plough*

or spade, fresh rain-water can the more easily soak into it, and do its work of changing insoluble matter in the soil into soluble plant-food, and of dissolving all that is already soluble.

This insoluble matter is often called *dormant* plant-food. The word dormant means 'sleeping,' and it is so called, because while it is in this state it is unable to do its work of feeding the plant. When it is changed into the soluble form, it is said to be in the *active* condition. Of course this work will not go on so well, if the water cannot gradually soak through the soil; hence, as I have already remarked, land should be well under-drained by means of pipes, if the water will not pass through it naturally.

69. But *when it is thus broken up and made soft, air gets into it easily as well as rain-water;* and the oxygen gas of the air, by combining with some of those substances which I have told you act as plant poisons, changes their injurious character, and so sweetens the soil and makes it more healthy. *And the plough, by turning the under-soil to the top, exposes just the very portion of the soil to the air which was out of its reach before.*

70. And this is not all the oxygen of the air does; for it helps the vegetable or organic matter of the soil, as it is termed, to decay or rot away. Now, when organic matter decays, some part of it becomes changed into carbonic acid; this is absorbed by the moisture in the soil, and thus the water gets a supply of this gas from the *soil* as well as from the air, for its work of rendering the dormant mineral matter *active.*

71. But in addition to carbonic acid, decaying organic matter yields other substances upon which plants feed; and the most valuable of these is **ammonia gas,** which is also readily absorbed by water, and about which I shall have to speak to you in a later lesson. The air, too, contains just a very small proportion of *ammonia;* and *freshly ploughed land frequently absorbs some of it* as it floats over its surface: and as a little of it goes a long way as food, and is, at the same time, very expensive to buy as a manure, even a very small quantity is worth catching in this way.

In this lesson I have shown you how the land becomes enriched with plant-food by being turned over and broken up, so that the rain and air may the more easily get into it, to work upon the particles of mineral and vegetable matter of which it

consists. But this is only one of the many purposes that the farmer has in view in breaking up his land. The late Mr Darwin has made public some wonderful facts in his interesting book on the 'work of the earthworm,' which he calls 'nature's plough.' He calculates that about twenty ounces of half-decayed vegetable matter—which is the chief food of the earthworm—passes through the body of each worm in a year, which, with the particles of the softer rocks, gets ground into a fine condition in its gizzard. At the same time, organic acids are formed from the further decay of this leafy food while thus undergoing digestion, which imparts to the water of the soil even a greater solvent power than carbonic acid does. In many parts of England, more than ten tons of earth in this very fine condition thus pass through the bodies of earthworms in a year on an acre of land. And this for the most part is brought to the surface; so that every few years the whole of the surface-soil passes through their bodies.

But further, the closing up of old worm-holes and boring of new ones keeps the soil in constant motion, and provides numberless channels for the drainage of water from the surface-soil. After this, who will look with contempt upon the humble earthworm?

LESSON XVI.—CULTIVATION—A MEANS OF CLEANING THE LAND.

72. There is nothing that gives a farmer or a gardener so much trouble as weeds. You know well enough that almost any soil will produce weeds, whether it be rich or poor, and a good farmer will be ashamed to have his land covered with weeds.

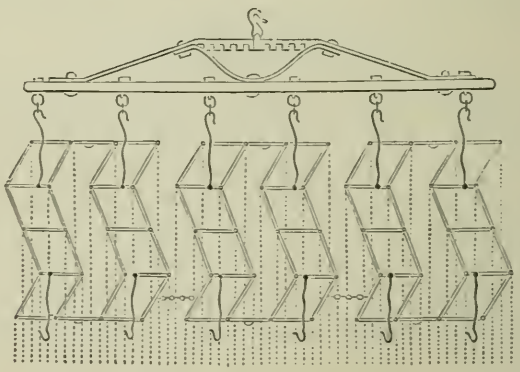
But the disgrace of being an untidy farmer is not the worst part of the matter; for you must remember that weeds are as much plants as wheat or turnips, and therefore they require the same kinds of food from the soil; and as they are always the plants best suited to the soil upon which they grow, they draw from it a greater amount of plant-food than those agricultural plants that may not be quite so well adapted for that particular soil, or of so hardy a nature. Weeds must therefore be looked upon as robbers. They rob the crops of their food, and the

farmer of his money, for it is his crops that he turns into money. So you see the importance of keeping land clean.

73. But it is not easy to keep large fields free from weeds, and especially of those kinds which, like couch-grass, rapidly spread in all directions underground, where their growth is not so plainly seen. If a field is well cleaned, and the crop gets a good start before the young weeds begin to grow, they will not flourish very well, because the stronger searching roots of the crop take most of the food, and leave little for the weeds. But if the weeds are allowed to take the lead, the crop will sadly suffer.

There is a famous fodder crop called Lucerne; it is in its nature and appearance between the clover and the vetch plant. And when a field is sown with this, it must be very thoroughly cleaned beforehand, and kept so for a year, that is, until the young plants have gained strength; after this, it needs no cleaning for years, because it grows so strong, and its roots search so thoroughly for food, that weeds cannot live at all with it. And this is true of all those crops whose roots spread rapidly, and are of a searching character; and also in a certain degree, of all crops. Strong growing crops, such as Scotch Champion potatoes, clean land by *smothering* the weeds.

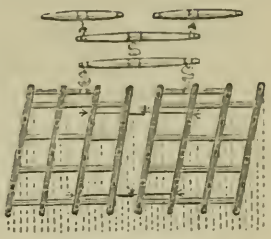
74. Now, the way in which *farmers clean their land*, is *by*



Howard's Harrow (iron).

ploughing it up, and breaking the lumps by means of the harrow and roller; in this way the roots of the weeds are brought to

the surface, and separated from the dirt to which they firmly clung before. The tines or teeth of the harrow then comb them out, and they are either gathered into heaps and burned, or killed by the heat of the summer sun.



Wooden Harrow.

75. Spring-time and summer are the times when this work must be done; before the seeds of the weeds have been produced and ripened. If weeds are allowed to remain till they have shed their seed, the farmer will find his work of cleaning immensely increased for the following year. Good farmers generally give each portion of their land a thorough spring and summer's cleaning once in four years; and also check the growth of weeds at other times when they have the opportunity, by means of the horse and hand hoe.

LESSON XVII.—CULTIVATION—A PREPARATION FOR SEED.

76. I will now simply describe a seed to you, in order that you may the more clearly understand what it requires during its early period of growth. Each seed contains a very tiny plant in its centre, called the germ, and enough food all around it to supply its wants until it has thrown out its first small leaves and roots. When this food is exhausted, the plant has to depend upon the *roots* for the several kinds of food which they suck up from the soil; and upon the *leaves*, for the one very important kind which they absorb from the air.

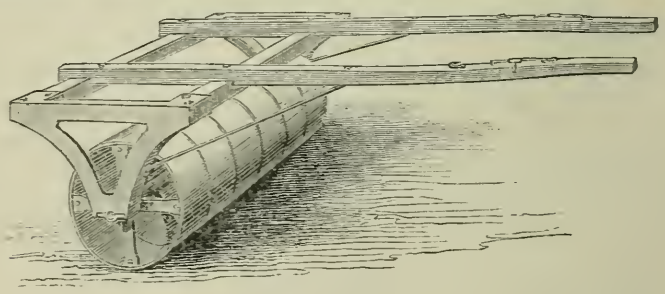
77. The growth that the germ makes from the supply of food which it has around it in the seed, is called **germination**. Now, germination cannot proceed without both air and moisture; because oxygen gas and water must soak into the seed to dissolve the plant-food in the seed, so that it may be absorbed by the germ to make it grow. The oxygen renders the food soluble, and the water dissolves it. Warmth is also essential to germination.

78. Again, the little roots have very fine hairs near their ends —too fine to be seen with the naked eye ; and it is these microscopic hairs that absorb the food from the soil. But in order to do their work, they must come into very close contact with the fine moist particles of the soil.

79. The *leaves, too, can only absorb the food, which they get from the* air, *under the influence of sunlight. Hence* it is necessary that *seed should be sown near the surface of fine moist soil,* in order that all these conditions may be satisfied.

80. If the soil has only been broken into rough hard lumps, much of the seed may drop down between the lumps, and be buried too deep for either the air to get to it, or the light to reach its first tiny leaves. Or the lumps may be too hard for the tender roots and leaves to push their way through. Or again, the root-hairs may not have a sufficient quantity of fine moist particles surrounding and touching them from which to draw nourishment. And so the seed may remain unproductive and perish.

81. So you see the great importance of getting a good *tilth* or fine seed-bed for the seed. And this is obtained by careful cultivation. On light and loamy soils, this can be obtained

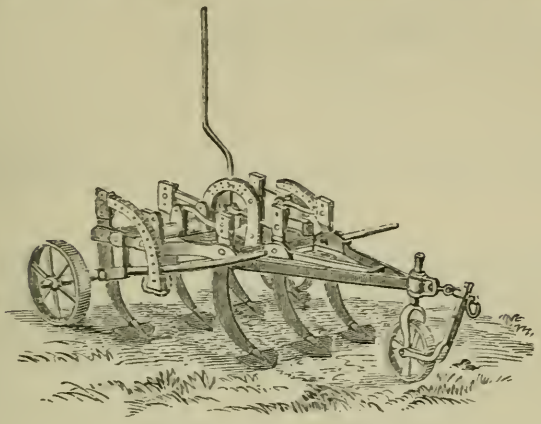


Horse-roller.

with no great difficulty by one or more ploughings, rollings, and harrowings. After the seed is sown in these friable—crumbly—soils, it is rolled again to press the mould closely round the seed, and to prevent the moisture being dried up as quickly as it would if the soil were left in a loose condition.

But on a clay soil it is no easy matter to get a fine tilth ; for after the ground has been broken up by the plough, either the

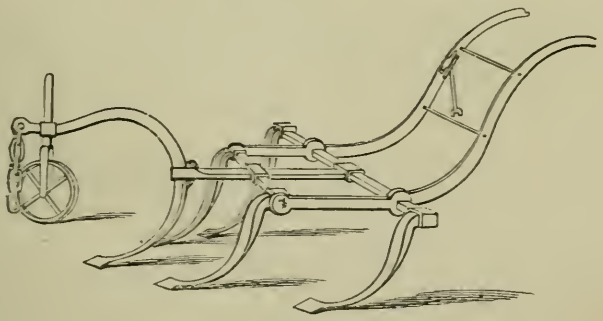
lumps, if dry, are too hard to be properly crushed by rolling; or else, if wet, only press tightly together into a mass. One



Coleman's Cultivator.

reason why clay land is not suitable for the growth of turnips, is, that the small seed requires a finer tilth than can be easily obtained on such land.

82. Stiff soils should be broken up roughly before winter sets in, and then the *frost will crumble the lumps down to a good tilth*



Tennant's Grubber.

by spring. The ground can then be stirred by a *cultivator*, also called a grubber, which will loosen the soil and draw out the couch, without burying the fine soil as a plough would do. The cultivator is an implement with several rows of curved

tines pointing forwards, and they can be set to loosen the land at as great a depth as the plough. Like the plough, it can be dragged by either horses or steam-engines, but it is very much harder work for horses than ploughing.

LESSON XVIII.—CULTIVATION—AN AID TO ROOT DEVELOPMENT.

83. Ordinary *ploughing breaks up land* to a depth of about six inches, *and brings fresh soil to the top.* But by spade-digging, land is broken up and turned over to the depth of nearly a foot; and consequently about double the amount of soil receives the fertilising influence of the fresh rain and air. This is one reason why spade-cultivation has been found so much better than ploughing. And the deeper the soil is cultivated, the more easily will the roots of crops be able to penetrate downwards in search of food. But by repeatedly ploughing at about the same depth, their downward progress is checked by the formation of a hard bottom called a *plough-pan;* and especially is this the case in stiff soils. This pan is caused by the constant treading of the horses which draw the plough, and the pressure of the plough at the same depth time after time. The sole of the plough, as it glides along, presses the particles of soil underneath closer together, and makes the bottom of the furrow smooth; much in the same way as a flat-iron presses and smooths starched linen.

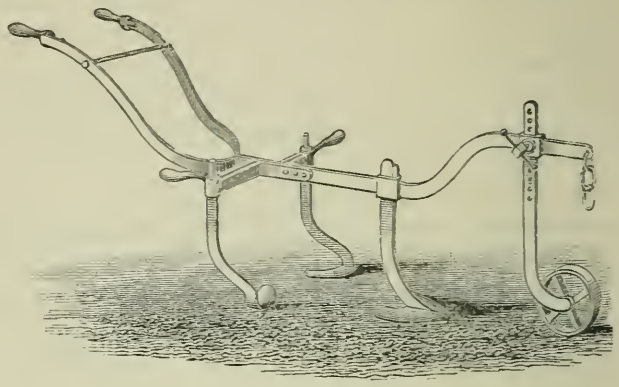
84. The soil that lies just below the surface which the plough turns up, is called the *subsoil;* and there is an implement called a *subsoil-plough*, which, while turning the surface-soil over like the common plough, *breaks up the subsoil* too by means of a deep-set tine. The work of drawing this plough is very great, and tiring to horses, and therefore cannot be continued for any great length of time at once. But the steam-plough, or steam-cultivator, can plough or grub up the land to a depth of about ten inches with the greatest ease, and very quickly. This monster never gets tired, and will continue to work as long as you supply it liberally with coal and water.

85. In this way the plough-pan may be thoroughly broken up, and a deep feeding-ground made for the roots of plants. And what an advantage this must be to the farmer! It is really enlarging his farm in the *quantity* of valuable soil, though not increasing it in *area*. This deep ploughing should always be done in the autumn, in order that the subsoil, which is of a less healthy character than the surface-soil, may be sweetened and improved for plant-growth in spring, by the action of the frost, and rain, and air.

86. The farmer has a convenient opportunity of doing this once in a rotation; for I must tell you that farm crops are generally grown in a certain order, and this order is called a rotation. The one most in use is the four-course rotation. Here a certain crop comes on the same ground every four years; and once during that time—namely, after wheat—the ground is thoroughly cleaned. This is the best time for *deep autumn cultivation on clayey land*. The wheat stubble should then be broken up and allowed to remain rough for the crumbling influence of the winter's frost. This kind of land should not again be ploughed in spring, but grubbed, so as to draw out the couch, without burying the fine soil. Autumn cultivation cannot be carried out, however, in very wet districts, such as are found in Scotland; for instead of the soil crumbling under the influence of frost into a fine powder, it would change into unworkable mud by spring. It is found better in such situations to plough the land up roughly in early spring, to be dried by the March winds. After thus being dried, the first soaking rain will reduce the lumps to a fine powder. *Light land is ploughed early in spring;* but late spring ploughing should not even be done to light land, as it causes the surface to become too dry.

87. The land that has thus reached the cleaning year of the rotation, is called the fallow, because the main purpose during the following spring and summer is not so much to produce a crop from it, as to thoroughly clean it, and expose it to the beneficial action of rain and air. If the land be a clay, and require much cleaning, it may be impossible to get it clean and produce a crop as well; it will then remain a *bare fallow* all through the summer. Generally, however, a valuable crop of

cattle or sheep food is grown upon the fallow ; but these *fallow-crops must always be planted in rows sufficiently far apart to allow of the soil being kept free from weeds* by hand and horse hoe,



Horse-hoe.

through the spring and early summer. Turnips and potatoes are very suitable fallow-crops for light soils ; and mangels and cabbages for heavy ones.

PRINCIPLES OF AGRICULTURE.

PART II.

LESSON XIX.—HOW RICH SOILS MAY BECOME POOR.

88. Crops, as you well know, are grown to feed people and animals; and, as I told you in the last lesson, the crops themselves are fed from the soil and air. Now, if every particle of animals and plants were given back again to the soil, you can plainly see that it would, on the whole, contain as much plant-food at one time as at another, and might even become richer, because some substances which had been first of all obtained from the air would afterwards be returned to the soil. But we know this is not the case, for animal productions, in the forms of milk, meat, wool, and hides, are being regularly carried away from the land where they were produced, to supply our shops with human food and clothing, and only to a small extent find their way back again to the fields.

89. And much the same may be said of many of the most valuable vegetable productions—the grain of wheat, barley, and oats, as well as fruits of all kinds. It is true the farmer takes care of the dung from the cattle, and such waste vegetable substances as straw, and returns them to the land again; and this prevents it becoming poor as quickly as it otherwise would. Then, too, the loss may be largely supplied by a portion of the insoluble plant-food in the soil becoming soluble; and in this way soils may yield good crops for many years together. But even then, in course of time, the soil must get gradually poorer; for year after year it gives away from *within* much more than it receives back again from *without*.

90. So if you were asked: 'What is the reason why people manure their land?' you might simply reply: 'To give back to the

soil the plant-food which some crop had previously taken out, that it may have plenty for the next.' And as I have just shown you, a farmer, by being careful of all his waste vegetable substances and the dung of his live-stock, will get enough manure to keep his land good, as long as the land can itself supply, little by little, some food to his crops also. But a time will come when his farmyard manure *alone* will not be sufficient to keep up the fertility ; and he will then have to supply the deficiency by buying artificial manures. By a wise use of these, not only can the fertility of the soil be kept up, but soils naturally poor may be rendered very fruitful.

LESSON XX.—IMPROVEMENT OF SOILS.

91. Before an attempt is made to improve anything, it is necessary first of all to find out where it is faulty. And so it is with soils; those who wish to make them better, must first of all find out what are their faults. In other words, if poor soils are to be made more fertile, the causes of their poorness must first be known.

92. In our lesson on fertile and barren soils, we learned that some of the causes of their poorness were wetness, sourness, coldness, and want of fresh air and fresh rain-water. Now, each of these faults may be set right by good under-drainage—that is, by laying lines of pipes underground ; they will carry away the water that is spoiling the land, and keep the surface-soil from being constantly in a soaked and sour condition. Fresh rain-water will then soak *through* it, instead of running *off* the surface, and will carry with it warmth, and gases that will improve the soil ; as it soaks down, too, fresh air will follow it, and sweeten and enrich the soil, as well as help the seeds to grow; and the sun's heat, instead of being all used up in drying the land, will be absorbed by it, and so make it warm enough for more rapid plant-growth.

93. You may have often seen corn-fields ploughed in narrow raised furrows, so as to form gutters for the water, that the upper parts might be drier; and you may have also noticed in such

fields the young corn looking yellow and sickly in the hollow parts, while on the top of each furrow it looked a much healthier green. This yellow appearance of either grass or corn is generally due to a wet soil. In winter, too, undrained land will frequently have a heavy mist hanging over it; and snow will lie unmelted on it longer than on the warmer drained land. Wet land ploughs up in a glossy, soapy state—unlike the more crumbly condition of well-drained soil. Then, again, wet meadows produce rushes, sedges, and marsh grasses, instead of the better kinds of meadow grasses and clovers. These are all signs to the farmer that he must improve his land by under-draining.

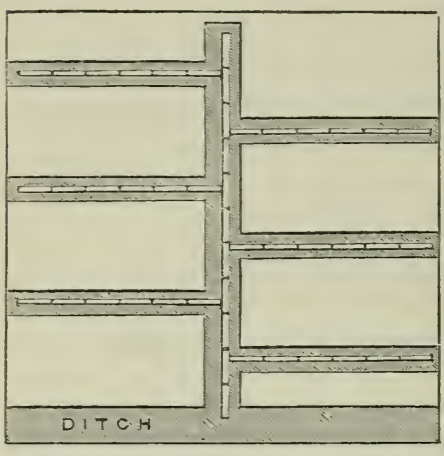
94. Another thing we learned in the lesson to which I have just referred, was, that **each kind of plant-food must be present in the soil in a state of solution, and also in a form that will gradually become soluble.** And to provide plants with these foods, is the very object that the farmer has in view when he manures his land. The farmyard manure, which is chiefly made up of the dung of farm animals, and straw in a rotten state, contains all the substances that plants require from the soil, both in a soluble and insoluble form—the phosphorus, the potash, the nitrogen, as well as the other less costly ones.

95. We have also seen that a soil **must not contain substances that are poisonous to plants**; and in order to render harmless those organic acids, and other substances that I have spoken of as plant poisons, the farmer has to apply *lime*, just in the same condition as it is used in making mortar. There is generally enough lime present in soils for the needs of plants as *food* simply; but *sometimes* he has to supply lime as a plant-food to such soils as peat soils, that contain very little of it in their natural state. For this purpose, unburnt lime in the form of chalk will do.

LESSON XXI.—DRAINAGE.

96. As the drainage of land is so necessary for the healthy and successful growth of crops, I will, in this lesson, endeavour to show you how the removal of water from the land is carried out by under-drainage. Just look at the diagram. It represents a

field that is being drained. You will notice that lines of pipes are laid down in parallel* trenches, and these all lead into a main drain, which is intended to carry the water that is drained from the whole field into the nearest ditch or brook, and thence into the nearest river. If the field were a narrow one, the parallel drains might all be made to run across the field into a ditch at once, instead of first discharging their water into a main drain. On the other hand, if the field were a very large one, *more* than one main drain might be necessary.



97. The pipes are about a foot long; and the hole in the small ones which are laid in the parallel drains is about two inches across; while the hole in the pipes of the main drain is about double the diameter of the smaller pipes.

98. The parallel drains in very stiff clay soils should not be more than five yards apart, and about a yard deep; while, in free-working soils, they may be as much as eight yards apart, and a foot deeper. The main drains should be three inches deeper than the others.

In laying the pipes, it is very important that a proper fall be given to them, so that the water and dirt may not have the chance to stand and collect. They should be laid gradually deeper as they get nearer the main drain; the fall should be about one inch in every six yards. You will notice in the diagram that the parallel drains on the opposite sides of the main drain do not enter it at the same points; and this is to prevent a collection of earth, or weakening of the main drain, in these places.

99. I must now try to explain to you how the water gets into

* Parallel lines are those that are the same distance apart from beginning to end.

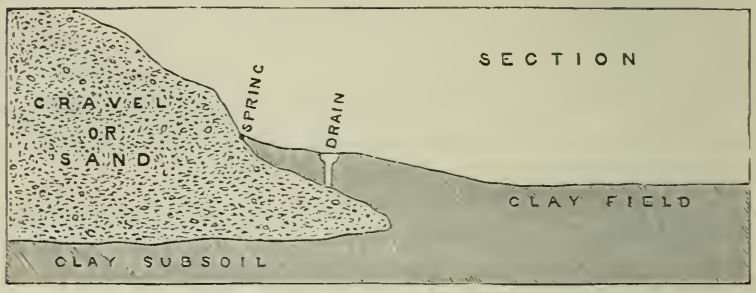
these pipes. It was always a puzzle to me as a boy, how the water which soaked straight down over a whole field could be collected in the lines of pipes which were placed so far apart; and I remember once asking a man who was laying the pipes, how it happened that the water found its way into them from such a distance on each side, and he replied, 'That they drew the water in.' I am afraid this answer will not satisfy you any more than it did me. The fact is, **the water does not go down into the pipes at all, but rises up into them.**

100. Let us just follow the course of the rain. First of all, we will suppose there has been a long, soaking rain in the autumn—the beginning of our wet season; this gradually sinks straight down into the soil, more and more follows it all through the winter, and it sinks farther and farther down, much below the level of the drain-pipes, scarcely any going near them. At last it comes to a bed of clay, or some close substance, through which it cannot soak. Having at last come to a standstill, it thoroughly soaks the soil which lies on this impervious bed. More water continues to sink down, and the pores of the soil get filled with it higher and higher, till it rises to the level of the drains. Now they begin their work of keeping the water down to this level. They will keep running as long as the land is in a thoroughly soaked condition above them.

101. If you placed a cask on its end, with the bung-hole half-way up, and poured water in from the top, directly it was full to the bung-hole it would begin to run out; and if you filled faster than the hole carried it away, the water would continue to run out of it after you had done pouring, till it was lowered to the level of the bottom of the bung-hole. This is exactly what takes place in the soil. You must look upon the impervious deep subsoil as the bottom of the barrel, the drains as the bung-hole, and the soil above as the part of the barrel above the bung-hole.

102. It sometimes happens that a clay field lying below the level of an adjoining gravelly or sandy bank or hill, is rendered too wet for cultivation by the overflow of a spring at a point where the two soils adjoin. In such a case, the clay field would be much better and much more cheaply drained by a single drain cut in the clay near the gravel bank, than by a series of parallel

drains. You will readily understand the reason of this by looking carefully at the diagram.



The rain which falls on the gravel readily sinks down to the clay subsoil; and as more and more sinks down, the water-level rises to the level of the adjoining clay, and there bursts out as a spring and overflows the field. Now, if a deep hole be dug near where the clay and gravel meet, it taps the saturated gravel below the level of the surface-soil, and the water rises into it and is carried away by the drain, as long as the gravel is saturated above the level of the bottom of the hole.

103. I have pointed out to you already the injury done to soils by being undrained (par. 62), and the benefits which arise from good drainage (par. 93).

LESSON XXII.—SIMPLE AND COMPOUND SUBSTANCES.

104. In the lesson on fertile and barren soils, you learned that all **plants require food** both **from the soil** and the **air**; and also, that the food which they get from the soil includes many different substances. I should like you to know something about these substances, in order that you may the better understand the composition of plants, of animals, of soils, of manures, and of the air. The science or study which teaches us about the composition of all these things is called chemistry. So I am really going to give you some lessons in chemistry; but

I promise you, they shall be very simple ones, and such as you will easily understand if you are attentive.

105. Years have been spent in trying by every known means to separate all things into the simplest substances or *elements* of which they are composed ; and now it is found that there are about **sixty-four elements** in the world which cannot be broken up into any simpler substances.

106. Many of these elements are of very rare occurrence, and are perfect strangers to you, while with several of them you are very well acquainted. Gold, silver, iron, lead, and sulphur or brimstone are elements well known to you ; they each consist of the one simple substance only. In this our subject of **agricultural chemistry**, we shall only have to deal with **fourteen** out of the sixty-four **elements**, because they are all that are of any importance in studying the composition of soils, plants, and animals.

107. But you must not expect to find these elements in their separate or simple condition, for this is not the form in which they generally occur in nature. They **exist in groups** of two or more firmly **joined** together in certain **fixed proportions** ; and these groups are **called compounds**. Common salt is a compound of two elements. Water is another compound of two elements. Sugar is a compound of three elements. And when the elements in each of these groups are closely combined together in the proper proportion to form the compound, their character becomes completely changed. I will give you an illustration of this: water consists of two elements, both of them gases, namely, oxygen and hydrogen; hydrogen gas will burn; oxygen will not ; but it will make other things burn much more brightly and fiercely. Now, water is a liquid—not a gas, and it will neither burn nor make other things burn ; on the contrary, it is the very thing that is used to put fires out. So you see that the compound—water—is not at all like either of its elements, hydrogen and oxygen.

LESSON XXIII.—SOLIDS, LIQUIDS, AND GASES.

108. All matter exists in one of **three states**—the **solid, liquid,** or **gaseous.** For instance, iron is a solid, water is a liquid, and air is a mixture of gases. But the same substance may be made to assume each of the three forms ; let us take water as an example. Under ordinary conditions, it is a liquid ; under the influence of cold, it becomes a solid—ice ; but if greatly heated, it assumes the invisible and gaseous form—steam. And here you notice that heat causes a solid to become a liquid, and a liquid to change into a gas. Iron, by the same agent, heat, may be melted or changed from the solid to the liquid state ; and by still greater heat, it would actually become a gas ; in fact, iron gas really does form a part of the atmosphere of the sun.

109. Some gases are elements, and some are compounds. *Hydrogen* and *oxygen* gases, which together form water, are, as we have said, each of them elements. *Nitrogen* gas, which I told you in one of our early lessons forms four-fifths of the air we breathe, is also an element. But *carbonic acid* gas is a compound, made up of two elements, carbon and oxygen. *Ammonia* gas is another compound, made up of two elements, both of which are gases—namely, hydrogen and nitrogen. Coal-gas is not one gas, but several compound gases mixed together. *Atmospheric air*, again, is neither a simple nor compound gas, but *a mixture* of the simple gases, nitrogen and oxygen, with a very small proportion of the compound gas, carbonic acid, and just a trace of ammonia.

110. Again, some gases are soluble in water, and some are not. **Carbonic acid** and **ammonia** gases are **very soluble,** while oxygen is only very slightly soluble indeed, and hydrogen and nitrogen are not soluble at all.

111. And now, if you understand that all the matter connected with our globe is composed of about sixty-four elements, a few of which are very plentiful, but three-fourths of which are scarce ; and that these elements generally occur combined in twos, threes, or fours, in fixed proportions to form compounds, very unlike the elements which compose them ;

and further, that these elements and compounds may exist in either the solid, liquid, or gaseous state, we shall be in a good position to continue our chemical studies.

LESSON XXIV.—ATMOSPHERIC AIR—OXYGEN AND NITROGEN.

112. The **air** which surrounds our globe consists mainly of two simple gases, **nitrogen** and **oxygen**—about four times as much nitrogen as oxygen. A very small proportion of **carbonic acid gas** is diffused or well scattered about in this mixture—about one measure in 2500 measures of air; and yet this small proportion is really an enormous quantity altogether, because the space through which it is diffused is so extensive. Besides these, water-gas, or **watery vapour**, as we generally term it, is always present in the atmosphere, and in a much larger proportion than carbonic acid gas—about one measure in every hundred, more or less, according to the state of the weather. There is also always a trace of **ammonia** in the air. In this lesson, and the next two, I wish to teach you something about each of these substances—*oxygen*, *nitrogen*, *carbonic acid* gas, *water*, and *ammonia*.

113. I will take **oxygen** first, because of its great importance. It is a kind of air or gas without either colour, smell, or taste; it will not itself burn, but if a lighted match be placed in it, the match burns with far greater brilliancy than in common air. It is the **oxygen** of the air which **supports** animal life, and **enables substances to burn**. If a lighted candle be placed under a glass shade, so that no more air can get in than is already there, the candle burns for a time, but soon goes out for lack of oxygen gas. An animal placed in oxygen, at first begins to feel a glow of pleasure, but soon gets into a fever of heat, and really lives at such a rapid rate, that before long it dies.

114. **Nitrogen**, like oxygen, is a gas without colour, taste, or smell, and will not burn; but, unlike oxygen, it immediately extinguishes a lighted match; and an animal placed in it, is unable to breathe, and therefore dies. It forms, as I have said, by far the largest part of the atmosphere, and its great use

seems to be to weaken the power of the oxygen by being mixed so largely with it; and so animals are prevented from living, and fires from burning, at the fearfully rapid rate that they otherwise would.

115. Oxygen seems such a friendly sort of gas, that it will combine with almost every other element without much difficulty; but nitrogen seems so *unfriendly* towards it, that although they are in such close company in the atmosphere, they remain separate, and will not combine. There is, however, a terrible power that actually compels them to cling together; and this power is the electricity which causes the lightning and thunder. During a thunder-storm, a very small quantity of a nitrogen oxide is formed from the nitrogen and oxygen; and this compound combines with a little water to form nitric acid. Nitric pentoxide is often called nitric acid, but it is only when it is combined with a proper proportion of water that it becomes the true nitric acid or aqua fortis of the chemist.

116. The little nitric acid that is thus produced in the air, is dissolved in the rain and carried into the soil, where it supplies plants with a most valuable food. You will easily remember what two elements form nitric oxide, from its name.

LESSON XXV.—ATMOSPHERIC AIR—CARBONIC ACID GAS.

117. Carbonic acid is a gas with a slightly sour taste; hence its name—acid. It immediately extinguishes a light, and destroys animal life. Sometimes it is called carbonic dioxide, which plainly shows that it is not an element like oxygen or nitrogen, but a compound of carbon and oxygen. And as carbon is a most important element in the chemistry of animals and vegetables, you should know something about it.

118. You have often seen carbon, and used it too, I dare say. The substance which is often called black-lead, but which has no lead whatever in it, is a pure form of carbon. Its proper name is graphite or plumbago; so remember when you use a black-lead pencil next time, you are writing with carbon.

Another pure and very beautiful and valuable form of carbon is the **diamond.** You can scarcely believe that that most valuable of all gems is simply a beautiful **carbon crystal!** You may get a pure form of carbon for yourself by holding a cold plate down on the flame of a lamp or gas-jet; the **soot** that will soon cover it **is carbon.** But a more common form than either of these, though not so pure, is **charcoal.** Charcoal is wood that has only been partly burned. The heat has driven off all the substances contained in the wood, except just the carbon and the very small proportion of ash which would have remained had the wood been *completely* burned. **Coke** is also an impure form of carbon; it is coal with all its materials driven off as gas by heat, except the carbon and ash. About **half the dry matter of all animals and plants consists of carbon.**

119. Whenever wood, coal, oils, and other substances which contain carbon are burned in the air, a great deal of the **carbon combines** with the **oxygen** of the air, **and forms carbonic acid gas.** Also when **animal and vegetable matter decays** or rots away, **carbonic acid is produced.** And when animals breathe, they take in the oxygen and nitrogen of the air and send out the nitrogen again unaltered; but the oxygen combines with some of the carbon of the food and of the worn-out parts of the body, and so **they breathe out** the poisonous **carbonic acid gas.** Fortunately, however, what is poison to animals is necessary food for plants. Their **leaves absorb the carbonic acid,** and the green colouring-matter of the leaves, *in the daylight,* very wonderfully makes the carbon and oxygen part company, driving the latter away, and **keeping the carbon to form a part of the plant itself.** So you see how wonderfully God has arranged for plants to feed themselves and at the same time purify the air for the needs of animals. You will remember that carbonic acid has the property of being very soluble in water, and of enabling rain-water to dissolve slowly the mineral matters of the soil.

LESSON XXVI.—ATMOSPHERIC AIR—WATER AND AMMONIA.

120. We next have to consider the **water** in the atmosphere. If you place a dish of water in the sun in summer, it soon gets dried up, as we say; that is, the heat of the sun changes the liquid water into invisible vapour—water-gas or steam. In this way our washed linen, and the puddles in our roads, are dried. But this evaporation takes place in cold weather as well as hot, though not to so large an extent. Evaporation goes on rapidly from the water of the ocean, and the **vapour** which rises **forms the clouds** that supply the earth with **rain.**

121. **Water** is a compound of the two elements, **hydrogen** and **oxygen,** in the proportion of two measures of hydrogen to one of oxygen. It is without any taste or smell when pure, and therefore does not flavour anything which is cooked or dissolved in it. This wonderful property which water possesses, of dissolving many substances, makes it the **carrier of food** for plants **from the soil to all parts of the plant**; and for animals **from the stomach to the blood-vessels, and** thence to **all parts of the body.** It also forms as much as **two-thirds** of the weight **of the living animal body**; and oftentimes **a much greater proportion of the living vegetable.**

122. The **hydrogen** contained in water is a simple gas like oxygen, without colour, taste, or smell. It will burn, but with a pale flame, unlike the bright white flame of coal-gas. It is the lightest substance known—only a sixteenth the weight of oxygen; so that, although there is twice as much hydrogen as oxygen in water by *measure*, there is eight times as much oxygen as hydrogen by *weight.*

123. **Ammonia** is a compound gas consisting of the elements **hydrogen** and **nitrogen.** It is very light, because it contains three measures of hydrogen to one of nitrogen. It has no colour, but it possesses the very powerful and pleasant smell of smelling-salts. It also has a stinging, burning taste, and is very soluble in water. A strong solution of it will quickly raise a blister on the tongue. It is always **produced when vegetable and animal matters decay,** from the hydrogen and nitrogen which they

contain ; just as carbonic acid gas is produced from the carbon and oxygen which these same matters also contain. As I have elsewhere told you, **ammonia** is one of the most **valuable** substances a farmer can have **in** his **manure or soil**, because **it contains nitrogen**, without which no plant can grow at all. I have tried in these lessons on the air to make you understand something of the four elements, oxygen, nitrogen, carbon, and hydrogen, and the compound gases which they form, and which occur in the atmosphere. And as these elements and compounds form a very important part of agricultural chemistry, you must read these lessons over carefully, several times, until you *remember* as well as *understand* their contents.

LESSON XXVII.—METALS AND NON-METALS.

124. The elements are very simply divided into two classes—**metals** and **non-metals**. Iron, copper, lead, gold, silver, &c. are metals, as you know; while sulphur, carbon, oxygen, &c. are non-metals. Metals are easily distinguished from non-metals by the peculiar glistening appearance which they all possess, so different from any other kind of polish. This shining appearance is called *metallic lustre*. Some of the metals which I have just named have nothing whatever to do with plant-growth, while there are several others, that are probably perfect strangers to you, without which plants cannot grow at all ; it is therefore of these latter that I shall have to talk to you.

125. The metals which **plants take up from the soil** are **potassium, sodium, calcium, magnesium,** and **iron**. There is also one other—**aluminium**—which **forms a part** of all **clay soils**, and is of considerable agricultural importance, but is *not* taken into the plant. All these metals exist as compounds with non-metals in the soil, not as elements; and therefore, if you remember what I told you about chemical compounds being altogether different in their appearance and properties from the elements which compose them, you will not be surprised that you have never seen these substances as metal elements glistening on the ground.

126. **Potassium** and **sodium** are light soft metals, very much alike in every respect, but difficult to get or keep in the pure state. When combined **with oxygen**, they **form potash** and **soda**. **Calcium** is the metal which is contained in lime ; in fact, **lime is calcic oxide**, or calcium and oxygen combined. The metals **magnesium**, **iron**, and **aluminium**, in like manner each combine **with oxygen** to **form** respectively **magnesia**, **peroxide of iron** or rust, and **alumina**. Remember, alumina forms a part of all kinds of clay.

127. The non-metals with which we shall have to do in agriculture are **carbon**, **oxygen**, **hydrogen**, **nitrogen**, **sulphur**, **phosphorus**, **silicon**, and **chlorine**. The first four we considered in our lessons on the air. The next, **sulphur** or brimstone, you are pretty well familiar with, in both the forms in which it is sold in the shops—namely, in thick round sticks called roll-sulphur, and in a powder called flowers of sulphur. It is one of the very few elements that are **found uncombined** in nature.

128. **Phosphorus** is not found free in nature like sulphur, but it can be obtained **from bones**, which consist chiefly of **phosphorus and lime**. When pure, it is in appearance very much like white wax. It has such an affinity for free oxygen, that it burns—smokes, but does not take fire—in the air, forming **phosphoric oxide**, and therefore has to be kept in water. Lucifer-matches are tipped with a substance containing phosphorus, to enable them to take fire when rubbed.

129. **Silicon** is one of the most plentiful elements in the world ; it is never found in the free state, but occurs in nature combined **with oxygen** to form **silica**. Silver sand and quartz are silica ; the sand of the sea-shore and flint-stone are impure silica ; glass also consists chiefly of silica.

130. **Chlorine** is a yellow gas, and if breathed, even in small quantity, causes a sore throat. Common salt, which you eat with your dinner every day, is a compound of this element and the metal sodium ; the chemical name for **common salt** is, therefore, **sodic chloride**, and from it chlorine gas can be obtained.

LESSON XXVIII.—OXIDES AND SALTS.

131. In our lesson on the metals and non-metals, you must have noticed that oxygen combines with each of them, thereby forming their oxides; and that more of them exist in the form of oxides than in the simple condition of elements.

132. There is yet another curious rule or law about these oxides, and a very important one too, and it is this: that oxides of the metals frequently combine with oxides of the non-metals to form compounds called salts. You are already familiar with one of these salts, namely, carbonate of lime. You may remember that I told you (par. 15) that when limestone or carbonate of lime is heated in the lime-kiln, carbonic acid gas, which is an oxide of the non-metal carbon, is driven off; and lime, which is an oxide of the metal calcium, remains behind. This plainly shows that carbonate of lime consists of carbonic dioxide and calcic oxide, or in other words, of carbonic acid gas and lime. For these several reasons, we shall in our future lessons more generally speak of the *oxides* and *salts*, than of the metallic and non-metallic *elements* in their uncombined state.

133. The metallic oxides are generally called bases, and the non-metallic oxides which combine with them, acids. But the latter are not, strictly speaking, acids; they are more correctly acid oxides; before they become true acids, they must combine with a fixed proportion of water. Water, by thus combining with these acid oxides, acts like a metallic oxide or base. Ammonia, too, when united to water, acts like a base, and forms salts with the acid oxides, very closely resembling the corresponding salts of potash and soda in their properties.

134. Oxygen has, however, a kind of rival in chlorine. This element unites directly with the metals as oxygen does, and by so doing, forms their chlorides. These chlorides are also called salts; as, for instance, common salt, which, as I have told you, is sodic chloride.

TABLE OF BASIC AND ACID OXIDES AND SALTS (for reference).

Base.			Acid.			Salt = Base and Acid combined.
Metal.	Oxygen.	Basic Oxide.	Non-metal.	Oxygen.	Acid Oxide.	
Potassium.	Oxygen.	Potash.	Nitrogen.	Oxygen.	Nitric Pentoxide, commonly called Nitric Acid.	Nitrate of Potash (Nitre or Saltpetre).
Sodium.	Oxygen.	Soda.				Nitrate of Soda.
Potassium.	Oxygen.	Potash.	Sulphur.	Oxygen.	Sulphuric Oxide, commonly called Sulphuric Acid.	Sulphate of Potash.
Ammonia.*	Water.	Ammonium Oxide.				Sulphate of Ammonia.
Iron.	Oxygen.	Oxide of Iron.				Sulphate of Iron.
Calcium.	Oxygen.	Lime.				Sulphate of Lime (Gypsum).
Calcium.	Oxygen.	Lime.	Carbon.	Oxygen.	Carbonic Dioxide, commonly called Carbonic Acid.	Carbonate of Lime (Chalk, Marble, &c.).
Magnesium.	Oxygen.	Magnesia.				Carbonate of Magnesia.
Calcium.	Oxygen.	Lime.	Phosphorus.	Oxygen.	Phosphoric Oxide, commonly called Phosphoric Acid.	Phosphate of Lime.
Aluminium.	Oxygen.	Alumina.	Silicon.	Oxygen.	Silica.	Silicate of Alumina.
Sodium.	*None.*		Chlorine.	*None.*		Chloride of Sodium (Common Salt).
Hydrogen.	Oxygen.	Water.	Nitrogen.	Oxygen.	Nitric Acid.	True Nitric Acid (Aqua Fortis).
			Sulphur.	Oxygen.	Sulphuric Acid.	True Sulphuric Acid (Oil of Vitriol).
			Carbon.	Oxygen.	Carbonic Acid.	True Carbonic Acid (only known in solution).
			Phosphorus.	Oxygen.	Phosphoric Acid.	True Phosphoric Acid.
			Silicon.	Oxygen.	Silica.	Silicic Acid.
Hydrogen.	*None.*		Chlorine.	*None.*		Hydrochloric Acid (Spirit of Salts).

* See par. 133.

LESSON XXIX.—THE ASH AND VOLATILE PORTION OF PLANTS.

135. You already know something of the composition of both soils and plants, but I want you to understand very clearly in what respects they are like or unlike each other in chemical composition. You know that all **soils** except peaty soils are **formed from rocks**, and therefore consist **mainly of mineral** matter; that they also contain **some organic matter**; and in the case of peaty soils, that they consist almost entirely of organic matter. Still, you have learned that plants contain mineral matter too, such as lime, potash, &c.; so that, without knowing anything more of the subject than you do at present, you would be able to say that soils generally consist almost entirely of mineral or inorganic matter, while **plants**, like peaty soils, consist **almost entirely of organic** matter; and herein lies the great difference between them in their chemical composition.

136. Now, it would not be at all difficult for you to find out for yourself exactly what proportion of mineral matter is in a soil or in a plant. Take a hundred ounces of perfectly dry earth, and the same weight of dry straw; heat the earth over a fierce fire in a ladle for some time, then set fire to the straw; now weigh what remains of the earth, and also the ashes of the straw; and you will probably have about ninety ounces of the earth remaining, but only five ounces of the straw. This is the whole of the mineral matter. The ten ounces of organic matter of the earth, and the ninety-five ounces of the straw, have been driven away by the heat in the form of gases and smoke. It is called the **volatile** or flying-away **part**; and consists of **carbon, hydrogen, oxygen,** and **nitrogen,** combined in the plant in various ways to form a large number of different substances. The heat breaks up their combinations, and drives some of the **carbon** off **as smoke,** and some more of it united to oxygen, as **carbonic acid gas**; some of the **hydrogen and oxygen** together **as water-vapour**; and some of the remaining **hydrogen** in company **with the nitrogen,** as **ammonia.** Now, although the straw and organic matter of the earth is destroyed, their elements are not; every particle of the ten and ninety-five ounces of organic volatile

matter is somewhere in the atmosphere, and will actually again form part of the solid substance of some other plants; for the carbonic acid gas will be absorbed by their leaves for the sake of the carbon, and the ammonia and water will be carried into the soil, and absorbed by their roots, for the sake of the nitrogen, hydrogen, and oxygen. There is no such thing as destruction of matter in the world; it may change its form, but cannot be destroyed.

137. The remaining mineral matter of the earth would probably consist of the following bases and acids:

Potash.	*Phosphoric Acid.*
Soda.	*Sulphuric Acid.*
Magnesia.	*Carbonic Acid.*
Lime.	*Silica.*
Oxide of Iron.	*Chlorine.*
Alumina.	

Of these, **silica is always plentiful**; and **lime, iron, and alumina generally** pretty **abundant**; while **phosphoric acid** is never present but **in very small quantities.** The ash of the straw would also consist of all these substances *except alumina;* they are therefore called the '**ash ingredients**' or '**ash constituents**' of plants. They are present in the ashes of all our cultivated crops, but not in the same proportions. For instance, **silica** is the most abundant ingredient of the ash **of the wheat-plant,** while potash and phosphoric acid stand next; **lime and potash** in about equal quantities are the most abundant constituents of the ash **of the clover-plant,** and again, phosphoric acid comes third; but **potash** is the *most* abundant in the ash **of the turnip-plant,** and lime and phosphoric acid take the second and third places. **Iron** is the **least abundant ash ingredient** of plants.

138. Now **oats, barley,** and **grass** closely resemble **wheat** in the composition of their ashes, and might therefore be called the **silica class.** They do, in fact, belong to the same class of plants—**the grasses**; you know how much like grass they look in the early stage of their growth. To this class also belong maize, rye, and many other plants.

139. Again, **peas, beans, vetches, lucerne,** and **sainfoin,** in like manner, closely resemble **clover,** and so might be styled the **lime**

class. And swedes, mangels, potatoes, and other root-crops having, like turnips, potash as the chief ash ingredient, might be named the potash class.

140. It has been found by the artificial mode of cultivating plants in bottles, where the roots absorb their food from specially prepared solutions of plant-food in water, that they can be successfully grown without silica, soda, or chlorine. Hence these are generally termed *non-essential* ash ingredients, and the remaining ones, *essential* ash ingredients.

141. Of course a soil must be able to supply to plants *all* the essential ash ingredients, or they cannot grow; and they frequently demand largely from the soil those ingredients which, like phosphoric acid, are least abundant. This substance forms a considerable proportion of the ashes of *all* classes of crops, and yet the most fertile soils seldom contain as much as a half ounce of it in a hundred ounces of dry soil. You must never think that a short supply of one constituent can be made up for by a plentiful supply of another. Plants require each of the ash constituents, and will only take them in their proper proportions. So you see, it is *the ingredient which is present* in an active condition in the soil *in the* least *proportion* that *regulates its fertility.*

LESSON XXX.—SOIL-FOOD OF PLANTS.

142. Crops not only depend on the soil for their ash constituents, but also for their supply of hydrogen, oxygen, and nitrogen. The two former are furnished by the water, which therefore fulfils the double purpose of first carrying in solution *all* the substances from the soil into the plant, and then itself combining with the carbon which the leaves absorb *from the air*, or with both the carbon and nitrogen, to form the great bulk of the solid matter of the plant itself. The nitrogen is supplied by the ammonia or nitric acid which is produced in the soil by the decay of organic matter, and also carried into the soil by rain from the air. The basic and acid ash constituents, as well as the nitric acid, are absorbed by the roots in their combined form of salts dissolved in water (see table, page 48). But

perhaps you will be surprised to hear that of a hundred ounces of dry earth, only about a quarter of an ounce is really soluble in water, and about eight ounces more are soluble in acids, and therefore will slowly dissolve in the weak carbonic acid contained in the water of the soil. And yet it is this soluble mineral matter that will form the *total* ash of the crop.

143. Before finishing this lesson, I must just say a word about the alumina, which, though abundant in all *clay* soils, plants neither require nor take in as food; and also about the iron, of which plants require very little indeed, although it is pretty plentiful in most soils. In the list of salts (see table, page 48), you will notice **silicate of alumina**, which is really very **pure clay**; now it has been found that the place of some little of the alumina in the impure silicate of alumina of a clay soil, is taken by soda, lime, potash, or ammonia; and so soluble **potash and ammonia**, which might easily be washed out of the soil, are **retained** in the forms of **double silicates of alumina and potash**, or of **alumina and ammonia**, which are not soluble. And yet these double silicates appear to be so loosely bound together, that they will readily give up the potash or ammonia and some silica to the roots of the plant in a soluble form.

144. Again, **iron-rust** (peroxide of iron and water) has a power of absorption, and by this power sucks up and **retains ammonia** for the use of plants (par. 71). **Alumina** and **peroxide of iron** are also able to **retain phosphoric acid** from being washed through the soil, and yet they give it up readily when the root-hairs of plants come in contact with them. So you see that, although alumina is not required by plants at all, and iron only to a very small extent, as food, yet they are particularly useful to crops, as servants to collect and retain plant-food till it can be used by the crops.

LESSON XXXI.—MANURES.

145. Having told you of the various substances which crops require from the soil, and explained to you their chemical composition, and the way in which soils become robbed of

them (pars. 137, 141, 88, and 89), you will now be able to understand the description I am about to give you of the various manures that are employed by farmers to supply the deficiency of any or all of these substances.

146. It has been found that, as a rule, **nitrogen, phosphoric acid,** and **potash** are the substances that require *chiefly* to be applied to soils to make or keep them fertile, the others being generally present in sufficient quantities for the immediate and future requirements of crops. There is, however, one notable exception to this rule in the case of peaty soils. As you know, they contain scarcely any mineral matter at all, and therefore require manuring with *all* the ash ingredients. So, after being well drained, these soils are thoroughly dressed with clay before being cultivated, in order that they may have the needful supply of mineral matter for crops. Lime is often largely applied to soils, but not so much as a plant-food, as to sweeten them, or to set potash free in a soluble condition for the use of crops, by taking its place in the insoluble portion of the soil.

147. Of the three most important manurial substances just mentioned, **nitrogen is the most expensive** to buy, but **phosphoric acid** is the one which **requires to be most largely purchased** by the farmer. I will explain to you the reason of this. The greater part of the phosphoric acid taken up by a plant is at last carried into the seed, so that a farmer, by selling his wheat and barley, removes the phosphoric acid which these grains contain completely from the farm. But the greater part of the potash, and almost all the silica and other ash constituents, are contained in the straw, and as this is mostly returned to the land again in the farmyard manure, the soil is not permanently robbed of them.

148. Again, the young animals that are reared on a farm require phosphoric acid to form their growing bones, for bones consist chiefly of phosphate of lime ; and fat animals that are sold off a farm for human food, carry away in their bones a great deal of phosphoric acid ; also milk, which is largely sold for human food, carries with it phosphoric acid, which would, naturally, help to form the bones of the young calf. Now in each of these cases the phosphoric acid has been obtained from the food which has been grown on the farm ; so

you see, a farm suffers a great loss of this scarce substance by rearing young stock, and selling fat stock or milk. The potash, on the other hand, is little needed by animals, and passes from them chiefly in their urine, and may therefore be returned to the land in the farmyard manure.

149. Much the same may be said of nitrogen as of phosphoric acid; it is largely contained in the seeds, and milk or flesh of animals that are sold off a farm, and is required to make the lean or muscle of young growing stock; but, as I have explained to you before, a small quantity is regularly carried into the soil from the atmosphere in the form of ammonia or nitric acid dissolved in rain-water, and leafy crops of the clover tribe also have the power of absorbing through their leaves some little ammonia with moisture from the atmosphere; so that by good management, much of the nitrogen which is sold off a farm will be again replaced without purchase.

150. Farmers have found that by buying **nutritious foods** for their cattle, such as oil-cake, they greatly increase the quantity of **nitrogen** contained in the dung; and so, with the natural supply just mentioned, they can replace the nitrogen sold off the farm. But if they wish to keep their land productive, they *must* buy phosphoric acid. I shall explain to you in a later lesson the various sources of supply of this substance; but I think you will now be able to see pretty plainly the reason why of the three important plant-foods—nitrogen, phosphoric acid, and potash—the phosphoric acid is the one which will pay the wise farmer best to buy most largely.

LESSON XXXII.—FARMYARD MANURE—ITS CHARACTER.

151. **Farmyard manure** consists of the **dung** and **urine** of farm stock, and the **straw** which has been used as litter. Of these, the dung contains nearly all the phosphoric acid, and the urine and straw nearly all the potash; the urine also contains the most nitrogen, but the straw scarcely any. From this, you will see that farmyard manure without the urine would be poor in

nitrogen, and would also lose a considerable amount of potash; without the dung, there would scarcely be any phosphoric acid; and by omitting the straw, there would be a loss of potash and other ash ingredients; besides which, the straw is necessary to absorb the liquid urine, and so prevent waste, as well as to render the whole of convenient consistency for easy removal.

152. A hundred pounds of well-rotted farmyard manure generally contains seventy-five pounds of water, a little *more* than half a pound of nitrogen, *about* half a pound of potash, and *less* than half a pound of phosphoric acid. Hence there is but one pound and a half of these three substances in the twenty-five pounds of dry matter; so that it is a most bulky manure, and therefore has to be carted in large quantities to the land, and requires some labour to spread it properly. From this, you will see that it is expensive in its application to the soil. And yet its bulk is of value; for it opens up stiff soils, and adds much humus to light soils, which helps them to absorb and retain moisture and ammonia for the use of a crop (par. 35). When rotten, it contains nitrogen, and all the ash constituents in a soluble condition, ready for the present use of the crop; but it also contains still more in an insoluble form, which becomes soluble by degrees, so that it supplies a crop steadily with food through the whole period of its growth. This is a great point in its favour.

153. **Farmyard manure** is termed a **general** manure, because it supplies *all* the kinds of food required from the soil by plants. Those which only supply one or two manurial substances to a crop are named *special* manures.

154. All farmyard manure is not of equal value, and for many reasons. Sheep's dung and urine are richer in nitrogen than those of other farm animals. Stock that are being fattened on corn, oil-cake, or other nutritious food, produce dung and urine richer in nitrogen than others. Young animals that require the phosphoric acid and nitrogen to help to build up their bone and muscle, take more of those substances from their food, and therefore produce a poor manure. Milking animals, too, produce a poor manure, because of the demand upon their food for the nitrogen and mineral matters required for the milk, so that the age and food of an animal, as well as the pur-

pose for which it is kept, greatly influence the quality of the manure produced by it.

155. Then, again, **farmyard manure** may be almost entirely spoiled by bad management; hence it is very important that a farmer should manage his manure in such a way as to prevent loss of valuable plant-food. And this is the more important from its being an expensive manure both to make and apply to the land, and yet so valuable as a food to all kinds of crops when really well prepared. It is not at all uncommon for the urine, which is of nearly double the value of dung, to be allowed to run to waste.

LESSON XXXIII.—FARMYARD MANURE—ITS PREPARATION.

156. Farmyard manure is principally made in the stock or fold yards in winter, when it is too cold for farm animals to be left in the open fields. Sometimes these yards are covered, but more frequently are open to the sky, with sheds on one or more sides for the shelter of the live-stock. When they are open, they receive the whole of the winter's rain, and therefore require much more straw to absorb the moisture and make them comfortable for the cattle. Sometimes you see a yard in a miserably wet state—the cattle half-way up to their knees in slush; in other cases, they are so well cared for, that they are almost knee-deep in clean straw. Now, in neither case are you likely to get a really good manure; for in the former a great deal of the valuable manure would probably run away in the gutters and be lost; and in the latter, the manure would consist of little else than straw. In order to obtain good manure from an open yard, and at the same time keep the cattle comfortable, the sheds should be troughed and spouted to catch the roof-water, which would otherwise stream into the yard; only just sufficient straw should be used as litter, to enable one to walk across the yard without getting more than the soles of the shoes damp; and a tank should be provided to collect all the liquid draining from the yard and stables, that nothing be lost. In a **covered yard**, less straw is required to keep the cattle comfort-

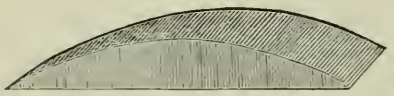
able and absorb the moisture, because no rain falls there, and so the **best manure** is obtained from it. Yard manure gets well mixed and pressed down by the cattle walking about on it; and when it reaches a depth of a foot or more, it is, on some dry frosty day, carted out of the yard and laid in a large heap.

157. The way in which this heap is made is a matter of great importance; but before I describe this to you, I must explain the chemical changes which go on in the manure-heap during its fermentation or *rotting*, in order that you may understand the reasons for the methods employed. **Fermentation** cannot proceed without the **aid of air**; consequently, the more loosely the manure is heaped together, the more easily will air get into it, and the quicker will it ferment; and the **closer it is pressed** together, the **slower will it ferment. In fermentation**, oxygen of the air combines with substances in the manure, and, as is always the case when oxidation takes place, **heat is produced.** You know how hot fresh stable manure gets, when placed in a heap for a cucumber bed. Now, **if water be poured** on the heap, many of the openings get filled with water instead of air, and the whole heap is cooled; consequently, **fermentation is checked.** So you see, both by pressing the manure tightly down, and also, if necessary, by a wise application of water, the heap may be made to ferment slowly.

158. But you will ask: 'Is there any advantage in causing manure to ferment slowly?' There is a great advantage. I have told you already that in the decay of organic matter, amongst other things, water, ammonia, and carbonic acid are produced; but besides these, *other* organic acids are formed from the contained hydrogen, carbon, and oxygen. You also know that **ammonia** with water acts as a powerful base (par. 133); consequently it readily **combines with** either **carbonic acid** or those **other organic acids** (humic acid, ulmic acid, &c.) to form salts. Now, **rapid fermentation** favours the production of carbonic acid, which combines with ammonia in the manner I have just described to form **carbonate of ammonia** (smelling-salts); but this is a very volatile salt, and therefore flies away into the air; and in this way the farmer may lose the nitrogen contained in the ammonia, which is so expensive and necessary for his crops. On the other hand, the **slow fermentation** obtained under the influence of

pressure and moisture, encourages the formation of the *other* organic acids, which also combine with ammonia; but the salts thus produced (**humate of ammonia, ulmate of ammonia,** &c.) are not volatile, and therefore do not escape into the air. They are, nevertheless, *soluble;* hence care must be taken that they do not *run* away, as they are often allowed to do, in the liquid which runs from a dung-heap. These are the substances which give the dark-brown (almost black) colour to the drainage-water of a manure-heap. In the rotting of the manure, much of the **other insoluble matter** also **becomes soluble,** and this, in like manner, may be carried off in solution.

159. Let us now return to the making of the heap. It should first of all have an **impervious bottom,** with some very absorptive substance, like dried peat, dry loam, or gypsum (sulphate of lime), laid on it to suck up the liquid manure. The heap should then be built high in the middle, and slanting down to the ground at each end; each load should be drawn from one end right over to the other side before being emptied; in this way the manure gets pressed very tightly down, load by load. The top should be made somewhat roof-shaped, to shed rain-water off, so that as little as possible may soak through. If the heap be made under a shed, loss from drainage will be saved, as in the case of the covered yard; but there may be a loss in gas, from the heap becoming too hot and dry. This may be prevented, and the manure improved, by pumping the liquid manure from the tank, over it, to cool and moisten it. Dung-heaps are sometimes covered with earth or sprinkled with gypsum to prevent the ammonia escaping.



LESSON XXXIV.—OTHER GENERAL MANURES.

160. In this lesson I am going to speak of a number of substances which, like farmyard manure, contain *all* the materials which plants require from the soil. Most animal and vegetable

substances are of this character. We will first consider **green-crop manures**. *Mustard*, *rape*, *turnips*, *vetches*, and *lupines* are frequently grown for the simple purpose of being ploughed in, while green, to improve the soil. While growing, they gather mineral matter, nitrogen, and water from the soil, and carbon and some little nitrogen, in the form of ammonia, from the air. When ploughed in, they therefore enrich the soil *only* by the little nitrogen they gathered from the air. But the mineral matter is returned in a much better form for the ready supply of the next crop than it was for *them*. They also add humus to the soil, and so greatly improve light land (par. 35); and the humic and carbonic acids which are set free in the soil by the decay of the humus, enable the water to dissolve *more* dormant mineral matter. **Green manures** are even more bulky than farmyard manures, for they contain more than 80 lbs. of water in each 100 lbs.; hence they render stiff soils more open, and so improve their texture. If grown in autumn, they use up the nitric acid which is in the soil, and so prevent its being washed through by the autumn and winter rains, and preserve it for the use of the succeeding crop. It is generally considered now, however, that as meat and milk fetch the farmer such good prices in the market, it is more profitable to apply these crops as manure in a second-hand way, by first using them as food for stock.

161. Near the sea-coast, **sea-weed** can often be obtained for the mere trouble of collecting it; and if ploughed in while fresh, it is very much like green manuring.

162. Peruvian **guano** is a very powerful general manure, and one of the most valuable artificial manures that can be obtained. It is particularly *rich in nitrogen and phosphoric acid*. It consists of the dried dung of sea-birds, which has accumulated in the course of centuries to a great depth on the coast of Peru, in South America. It is an excellent form for top-dressing corn or grass crops.

163. Dried **blood** and **fish** are good general manures; the former containing the mineral matters which make bone, as well as the nitrogenous substances which form lean; and the latter being really that of which guano was formed, for the sea-birds who deposited the guano lived on fish.

164. **Oil-cakes** and **malt-dust** are sometimes used as manures, and are very valuable ones too; but they are also such nutritious foods that it is much more profitable to use them first of all as foods; they will then, in the second place, enrich the manure-heap. The oil-cake made from rape-seed is not much relished by cattle, so that it is cheaper than other kinds, and may be used profitably as a manure. These substances are more valuable for the nitrogen which they contain than for the mineral matters.

165. Woollen rags and **woollen wastes**, such as the 'shoddy' of the cloth factories, as well as **hair, clippings of hides, horns, and hoofs**, are used as manures, and are mainly valuable for the nitrogen they contain. They might therefore be classed among the special nitrogenous manures. Woollen rags and wastes, as you would imagine, are very slow in decaying, and therefore yield up their nitrogen very gradually; but they are lasting, and are often used as hop manures.

LESSON XXXV.—PHOSPHATIC MANURES.

166. We now commence the consideration of *special* manures, that is, those that are applied for the purpose of adding certain special substances *only* to the soil, and not *all* those required by crops. And as I have already explained, phosphoric acid requires special application more generally than others, because it is never plentiful in the soil, and yet is largely carried quite away in the grain, bones, or milk that are sold off a farm.

167. We will start from what you know already, namely, that **bones** consist mainly of **phosphate of lime**. But there are three phosphates of lime—*tri-calcic phosphate*, or three-limed phosphate; *di-calcic phosphate* (also called bi-calcic phosphate), or two-lined phosphate; and *mono-calcic phosphate*, or one-limed phosphate. The first of these is the one which occurs in bones, and is not at all soluble in water; the second is very slowly soluble; and the third, which is called **superphosphate**,

is very readidly soluble. The following table will perhaps make this matter clearer to you:

Base.	Acid.	Salt.
Lime Lime Lime	+ Phosphoric Acid =	*Tricalcic*, or insoluble *bone* phosphate.
Lime Lime Water	+ Phosphoric Acid =	*Dicalcic*, or very slowly soluble phosphate.
Lime Water Water	+ Phosphoric Acid =	*Monocalcic*, or very soluble *super*-phosphate.

From it you will see that phosphoric acid requires three equivalents of base, either lime or water, to form either of the three calcium salts; and it will also explain to you why the last is named *super**-phosphate, namely, because the proportion of phosphoric acid to lime in *it*, is much greater than in ordinary phosphate.

168. Bone phosphate was the only one used at one time; the bones were broken into pieces called **half-inch bone**, and when spread on the land, were very slowly dissolved by the carbonic acid of the rain, and furnished to crops. If, however, raw bones, which have had the fat first removed from them by steaming, are ground into **bone-meal**, and applied to the soil, good results are apparent much sooner, because the phosphate of lime is more diffused through the soil; and, being in a fine state of division, is much more quickly made soluble for plant use. Raw bones also contain much organic matter, which will yield nearly four per cent. of nitrogen.

169. Since then, large stores of **tricalcic phosphate** have been discovered in various parts of the world as **minerals**, in the forms of fossils or pebbles called **coprolites**, and of rock called **phosphorite**. The chief coprolite diggings are in Cambridgeshire and neighbouring counties, and in the state of South Carolina in North America; phosphorite is imported chiefly from Spain, France, and Canada. These **mineral phosphates** are very hard,

* *Super* = above, or in excess.

but if ground to powder and applied to soils which contain much humus—old meadow or peaty land—they are gradually dissolved by the humic and carbonic acids which the decay of the humus produces, and prove most valuable manures.

170. In the year 1840, the great German chemist, Baron Liebig, made known his discovery, that insoluble **tricalcic phosphate** could easily be **changed to the very soluble monocalcic phosphate**, and be ready for root-absorption at once. This led to the establishment of manure works in a great many places, for the manufacture of **superphosphate of lime.** In this process, the bones or mineral phosphates are treated with sulphuric acid (oil of vitriol), and the change is produced which is shown in the following table :

	Base.		Acid.		Salt.
Before the change.	Lime Lime Lime	+	Phosphoric Acid	=	*Tricalcic Phosphate.*
	Water Water	+	Sulphuric Acid Sulphuric Acid	=	*Oil of Vitriol* (True Sulphuric Acid).
After the change.	Lime Water Water	+	Phosphoric Acid	=	*Monocalcic Phosphate.*
	Lime Lime	+	Sulphuric Acid Sulphuric Acid	=	*Sulphate of Lime* (Gypsum).

So you see, the change is simply this : that the phosphoric acid has given up two-thirds of its lime to the sulphuric acid, and received water in return ; and the result is, **a mixture of monocalcic phosphate and sulphate of lime,** which is **the superphosphate** of the manure manufacturer.

171. Now, monocalcic phosphate is a very acid salt—perhaps too acid for the immediate use of plants ; but it has been found that, being soluble, it easily gets diffused in the soil, but cannot remain soluble long, for either lime, iron, or alumina (par. 144) will take the place of the water, and reduce it to a less soluble state. A great many experiments have shown that a mixture of **bone-meal or ground mineral phosphate with superphosphate, produces a much healthier growth and better yield than**

superphosphate alone, and is much cheaper; the price of superphosphate being about double that of the tricalcic phosphate. By thus mixing the most soluble and least soluble phosphates together, a more natural and lasting plant-food is produced, resembling the middle or slowly soluble phosphate, produced by the action of the very weak carbonic acid on the tricalcic phosphate in the soil. The superphosphate produced from bones is generally called '**dissolved bone**,' to distinguish it from '**mineral superphosphate**.' The mixed phosphate may be called '**reduced superphosphate**.'

172. Phosphatic manures produce a wonderful effect upon root-crops, which come once in a rotation; and as these are eaten on the farm, a great deal of the phosphoric acid is returned to the land, in a suitable form, for the use of the corn-crops which follow. These, in the last stage of their growth, take nearly all the phosphoric acid which they have gathered from the soil, up into the seed. It is therefore a seed-forming manure, and favours early maturity in corn-crops.

LESSON XXXVI.—NITROGENOUS MANURES.

173. *All* the **general manures** which we have noticed are valuable **nitrogenous** manures; but those that we are now going to consider are special manures, bought and applied by the farmer, *solely* for the nitrogen which they contain. The first is, **nitrate of soda**, which is brought into this country from Peru and Northern Chili in South America, where it occurs in immense beds many feet thick. Being so soluble, it is a very rapidly acting manure, especially on grain and grass crops; in a few days it will change a sickly yellow corn-crop in spring, to a dark healthy-looking green. But its effect is greater on the leaf and straw than on the grain; it is usual, therefore, to mix ¾ cwt. of nitrate of soda with about three times as much common salt, as a dressing for an acre of corn, to prevent a too luxuriant growth of straw at the expense of the grain. This is not so necessary for grass, because it is grown for its leaf and stem, and not for its seed. **Nitrate of soda** also has a very **good effect on mangels and cabbages**. It is more easily washed out of the soil

by rain than any other manure, and therefore **should be applied** as a top-dressing to crops while they are **in active growth**, and able to use it at once, and not during the rainy periods of late autumn and winter; April will therefore be about the best time.

174. Nitrate of soda is called a plant **stimulant**, because it gives a plant a sudden activity of growth, which enables it to gather more rapidly from the air and soil the substances which it requires, other than the nitrogen supplied in the nitrate itself. Hence land should be well supplied with those other ingredients that it is deficient in, before nitrate of soda is applied, or it will surely impoverish the land for the next crop. This is the reason why nitrates have proved *most beneficial when used with phosphatic manures.*

175. **Sulphate of ammonia** is another special nitrogenous manure, and is considered as valuable as nitrate of soda; it is not quite so rapid in its action as nitrate, but it is not so easily washed out of the soil. It is obtained from the ammonia liquor of gas-works, by mixing with it sulphuric acid.

176. **Soot** contains a small percentage of sulphate of ammonia; hence its value as a top-dressing for spring corn.

LESSON XXXVII.—POTASH MANURES.

177. **Potash** is not so much required as a special manure as either phosphoric acid or nitrogen, because it is contained in many soils in sufficient quantity for the wants of most crops; and also, because it is nearly all returned to the soil year by year (pars. 147 and 148) in the farmyard manure, especially when the urine is returned. It has, however, in many cases greatly improved the crops of the clover and root classes of plants, which require a great deal of this ash ingredient; but especially has it been found an **excellent potato manure.**

178. **Nitrate of potash** (nitre or saltpetre) is the most valuable of all potash manures, because the nitrogen which it contains, *alone* makes it as valuable as nitrate of soda as a nitrogenous manure. But this salt is the one chiefly used in the manufacture

of gunpowder; and the great demand for it for that purpose causes it to be too expensive for purchase as a manure.

179. The reason why I mention nitrate of potash here as a manure, though never bought by farmers for that purpose, is, because there are ways in which they can produce it for themselves roughly. Whenever animal matters (such as clippings of hides, dung, urine, &c.) are mixed with lime and vegetable substances, or earth containing potash, and exposed to the air, nitrate of potash is formed. If you look at our table of salts (see page 48), you will see that nitrate of potash consists of potash, nitrogen, and oxygen. The nitrogen is supplied from the animal matters, and some too from the vegetable substances; the oxygen from the air; and the potash from the earth, urine, and vegetable matters. The lime combines readily with the nitric acid which is first produced, and then the potash displaces the lime. The potash will not so readily combine with the nitric acid as the lime; hence the use of the lime to start the combination.

180. When lime is applied to a soil that has been well manured, and opened up well by tillage for admission of air, the change which I have described, slowly takes place; and so this valuable manure, *nitrate of potash, is produced in the soil.* Careful farmers also collect the clippings of hedges, scourings of ditches, and other like refuse matters, mix them with lime, and form them into what is called a compost heap; by so doing, they are preparing a certain quantity of nitrate of potash, to enrich their land with.

181. There is, however, one material which is cheap enough to be purchasable by the farmer as a special potash manure; and that is **Kainit.** This substance is found in large quantities at Leopoldshall and Stassfurt in Prussia (near Magdeburg), overlying an immense bed of rock-salt at a great depth below the surface of the earth. Kainit consists of a mixture of chlorides and sulphates of potash, soda, and magnesia. Now, as you know, chloride of soda (common salt), if applied *directly* to vegetation, destroys it; therefore kainit must not be applied in this way. Mr Clement Cadle has proposed that farmers should mix kainit with the farmyard manure as they cart it into the heap; it will there undergo a gradual change; the potash will probably combine with the nitric acid, produced in

the fermentation of the manure, and thus form the valuable nitrate of potash we first spoke of in this lesson ; besides which, the sulphates and chlorides have the power of 'fixing' the ammonia (par. 159). The manure from such a heap, when thoroughly rotten, would prove an excellent one for top-dressing a young clover crop.

LESSON XXXVIII.—LIME—I.

182. I need hardly remind you that lime is one of the chief ash constituents of the clover and root classes of crops (par. 137), and is contained in smaller proportions in the ashes of all other classes of plants ; it is therefore a very important plant-food. By a dressing of lime, fields have been known to bring forth common white clover, where nothing of the sort had been seen before ; and so lime frequently improves pastures by causing highly nutritious wild plants to spring up for the first time. In this way it greatly benefits clay soils that are sometimes deficient in a natural supply of lime, and peaty soils that are also poor in this and other mineral plant-food. Light dressings applied to worn-out pastures often quite change their character for the better.

183. And yet, except in the cases just mentioned, lime is not applied to soils so much for the purpose of feeding crops directly itself, as for setting free the dormant plant-food of the soil for their use. I will endeavour to explain to you the many ways in which it thus liberates these valuable substances.

184. Potash and soda are bound up with silica and other mineral substances in the insoluble rocky particles of the soil, and in this condition are unable to feed plants ; but, as you know, water containing carbonic acid is able very slowly to dissolve the potash and soda out, and so break up the combination ; but lime is such a powerful base that it can do this work *quickly ;* it turns out the bases, potash and soda, and takes their place. They are thus set free to form compounds with any acids they can find in the soil ; but the compounds which they then form are soluble, and can therefore be absorbed by the roots of plants. Exchanges of this kind are constantly going on in the soil.

185. You will remember that in our last lesson **lime** was the **active base** in combining with nitric acid, but was afterwards **replaced by potash**, to form nitrate of potash. You may also remember what I told you about the use of alumina in the soil (par. 143), to retain potash and ammonia in the loosely combined form of double silicates, ready when required to give up potash, ammonia, and silica to the plant. Now, **lime** is the **active base** which generally begins the formation of these **double silicates** by taking the place of part of the alumina that is combined with the silica. But the double silicate of alumina and lime once being formed, the potash or ammonia will easily replace the lime.

186. So **lime**, by **liberating potash and soda** from the dormant mineral matter of the soil, and helping to **form nitrate of potash**, and the **double silicates** in the soil, prepares a great deal of important plant-food for the use of all kinds of crops.

187. But this is not all; it is even more destructive to the organic matter of the soil, than to the mineral portion; causing it to quickly break up into water, carbonic or other organic acids, and ammonia. So here again it **sets free the nitrogen** as a plant-food from its dormant state.

188. You will plainly see from all this, that if lime were applied constantly alone to the land, the land would become gradually exhausted of those substances set free by the lime, and really would be made poorer and poorer. **Lime** is, therefore, an **exhaustive** manure.

LESSON XXXIX.—LIME—II.

189. There is another use of lime that you have before heard something about (par. 95)—namely, that of **sweetening sour land**, and thereby making it more suitable for the growth of farm crops. Land is soured by the decay of vegetable matter in a wet state, and the consequent production of certain organic acids. Lime combines with these acids, thereby forming salts which are not at all acid in character.

190. Now, there are two ways in which all these changes may be brought about by the use of lime—a slow, and a very quick way. If **chalk** (carbonate of lime) be used, these changes are all

brought about very slowly; but if **quicklime** (burnt lime) be applied, they take place very **rapidly**. Quicklime should never be used in a sandy soil, because it soon destroys the vegetable matter in it, which helps to keep such a soil cool and moist, and to retain soluble manure in it. And even on clay soils, which are *naturally* retentive of moisture, it should only be used once in a few years; and the land should at other times be well manured, because of the exhaustive character of the lime. It may be used on peaty soils, as they contain an almost unlimited amount of vegetable matter, and are generally at first sour. It may also be used with advantage on stiff clays, for they are the ones where the double silicates can be formed. It is often used, too, on old pastures when first broken up, to bring the large amount of organic matter, which has accumulated in the course of years, into a serviceable condition for the crop intended to be next grown. Under other conditions, the slowly acting *carbonate* of lime *only* should be applied.

191. When quicklime is to be used for the land, it should be placed in small heaps over the field; water should then be poured on each heap to slake or crumble the lumps to powder; the heaps should at once be covered with earth, to prevent, as much as possible, the carbonic acid gas of the air being absorbed; and it should, without loss of time, be spread over the field, and harrowed in. Lime has a great tendency to sink into the soil of itself, so should not be ploughed in. If it be exposed to the air, or allowed to remain in heaps for long, it will absorb carbonic acid gas, and a good deal of it will be converted into carbonate of lime again.

192. There is yet one more important use of lime. **It improves the texture of soils**; and for this purpose can be used as chalk. Coming, as it does, midway between sand and clay, it helps to make sandy soils more retentive and firm, and clays more open and friable.

193. **Marls** are frequently used for this purpose; they are mixtures of clay and chalk, and frequently contain small quantities of phosphoric acid, and other ash ingredients. When containing a large proportion of clay, they are especially valuable to sandy and peaty soils, both as manures and consolidators.

PRINCIPLES OF AGRICULTURE.

PART III.

LESSON XL.—SEED—I.

194. Having described to you the **soil and air** from whence plants derive their natural feeding materials, and **manures** of different kinds as **supplemental** or additional sources of food-supply, it remains for me now to give you some account of the **crops** themselves. And when you think of the many different farm crops that are grown, and of their several habits of growth, their favourite soils, the climates for which they are best adapted, and the modes of cultivation which farmers have found best suited to their full production, you will at once see that we shall find much to talk about.

195. But amid these manifold differences, there are certain habits of growth common to *all* farm crops: they are all produced **from seed**; they all have **roots, stems, and leaves**; they all have one object in growing, namely, to **produce seed**; and they all obtain their food from the same sources—the soil and air. Before considering their unlike characters, therefore, I will first describe simply to you the **life-history** common to them all.

196. A plant's life begins in the seed—when the seed is placed under influences favourable to its development into life; just as a bird's life begins in the egg when it is subjected to the

favourable influence of warmth. In fact, a seed and an egg are in many respects similar to each other. In the middle of an egg there is a tiny embryo or germ which develops into the young bird; this is attached to a mixture of very nutritious oily food—the yolk or yellow part; and this again is surrounded by another lean-making food—the glair or white portion; under the influence of warmth, the embryo is able to absorb and feed on the yolk and glair, and thus, in some wonderful way, known only to the Great Creator of all things, to assume gradually the form of a perfect bird. And lastly, the whole is inclosed in a covering—the shell, through the tiny holes of which, air can get without much difficulty. Eggs that do *not* contain the embryo are good enough for food, because they still contain the yolk and glair, which are the feeding portions of an egg; but they would never produce young birds, for the germ of life is absent. Neither will stale eggs produce living birds.

197. **A seed, too, contains a germ**, which, under favourable conditions, has the wonderful power of absorbing the food which surrounds it in the seed, and developing into a living plant. And this food, like the food in the egg, contains **fat-making, lean-making, and bone-making materials.** The seed also has a **covering** through which air can be absorbed; and it, too, loses its vitality (power of living), if kept for too long a time; this is why old seed, when sown, frequently fails to come up.

LESSON XLI.—SEED—II.

198. I want you very clearly to understand the substances that are contained in seeds as germ-food, and the changes which they undergo during the process of germination. Let us take some wheat seed, and first of all divide it, by burning, into its **ash and volatile matter.** We shall only get about two per cent. of ash, nearly half of which is phosphoric acid; we may consider this small amount of **mineral matter in the wheat-grain** as the **bone-forming portion** when it is eaten as food.

199. But we must carry our inquiry farther than this. We

will now take some wheaten flour, which is the whole of the powdered wheat-grain except the bran or seed-covering, which has been removed by sifting; and after mixing this flour with a little water into a dough, we will repeatedly wash and squeeze it, till the water squeezes out quite clear. We now have remaining a sticky substance, that will bear being stretched considerably before breaking, and which for this reason is called **gluten**. It very closely resembles the lean of meat in its chemical composition, although so unlike it in appearance, and actually *forms* the lean of the animal that eats it. It consists almost entirely of carbon, hydrogen, oxygen, and *nitrogen*.

200. We must next turn to the water with which we washed the dough. After being allowed to stand for some time, we notice a white settling at the bottom; this is **starch**. If we pour the water off and dry it, it will closely resemble arrowroot, which is also pure starch. It consists of carbon, hydrogen, and oxygen *only*, and in this respect is like sugar and fat; and when eaten, it is actually changed into sugar, and is partly used to form the fat of the body. Wheat contains about six times as much starch as gluten.

201. So you see, a wheat-grain mainly consists of **starch**—a *non-nitrogenous or fat-forming substance;* and **gluten**—a *nitrogenous or lean-forming substance*, with just a very little **mineral** or *bone-forming material*.

202. Now, although all seeds do not contain starch and gluten, they all either contain these or other non-nitrogenous and nitrogenous substances which perform the same duties of producing fat and lean when used as foods. The seed of the flax or lint-plant (linseed), for instance, contains oil instead of starch; but, as I before remarked, this, like starch, consists of carbon, hydrogen, and oxygen only. And this is true of all those seeds from which oil is expressed (squeezed out of). Again, seeds of the clover and bean class of plants contain a nitrogenous substance called **legumin** instead of gluten, and for this reason are called legumes or leguminous plants. Legumin is a substance closely resembling the curd of milk, from which cheese is made; and it is the *curd* of milk which forms the lean of the young animal that feeds on it.

203. I may also here mention that gluten and legumin are

frequently called **albuminoids**, because they are nitrogenous, flesh-forming substances like **albumen**—the chemical name for the glair or white portion of an egg.

LESSON XLII.—GERMINATION OF SEED.

204. We have now to consider the *changes* which take place in the germination of seeds. You will remember I told you (par. 77) that the favourable conditions for healthy **germination** are, a certain amount of *warmth*, *moisture*, and *air or oxygen;* and that germination is the first growth of a plant which takes place while it is supported by the food in the seed alone.

205. **Moisture** is first **absorbed**, and soaks from **cell** to cell of the seed, softening the whole, and causing it to swell out. **Oxygen** is also **absorbed**, and by combining chemically with some of the substances in the seed, produces some little extra heat. And now a small quantity of a new nitrogenous substance is formed close to the germ, probably by oxygen combining with a portion of the albuminoid in the seed, or, as chemists would say, '*by oxidation of an albuminoid.*' And this substance is named **diastase**. Try to remember its name, for it has a most important duty to perform; nothing less than to **change** the whole of the **starch**, or other non-nitrogenous substance of the seed, **into sugar**, so that it may dissolve in the water absorbed into the seed, and so be carried into the germ or tiny plant, to feed it and make it grow. It also **renders** the **albuminoids soluble**, so that they too may be absorbed by the germ in like manner.

206. The work of growth now very soon begins; the tiny thread-like *roots first shoot out* in a downward direction, and before long the tiny germinating leaves make their appearance upwards. Growth continues in this way till the seed is exhausted of all its food. And now a new stage in the life of the plant begins; the young plant must, during the remainder of its life, depend entirely upon its **roots** for a supply of **soil-food**, and upon its **leaves** for a supply of **air-food**.

LESSON XLIII.—GROWTH—OFFICE OF LEAVES—I.

207. In our last lesson I described to you the first stage of a plant's life—germination. Its real life now begins independently of the seed; and the young roots and leaves—its proper feeding organs—now commence their work. We will follow the food as it is conveyed through the plant, and notice the chemical changes which occur.

208. The root-hairs, which absorb the food from the soil, are only to be found on the youngest, thread-like roots, and not even at the ends of these. As the roots get older and thicker, they lose the feeding hairs, and therefore become useless as a means of absorbing food from the soil; but they still have to perform the important duty of *holding the plant firmly in the ground.*

209. The nitrogen and ash ingredients which occur in the soil as salts, become dissolved in the rain-water; and in this state enter the root-hairs, which are really microscopic tubes. This weak water-solution of the various salts* is the sap of the plant in its *crude*, that is, unprepared state. In this condition it moves upwards into the stem, and along its ducts into the veins of the leaves.

210. If you look at a leaf, you will notice that smaller veins branch off from the central one in all directions, getting finer and finer as they near the edge of the leaf. By means of these innumerable branches, the crude sap is conducted into every part of each leaf. As yet, this sap has added nothing to the substance of the plant; none of it has actually changed into the fibre or solid matter of the plant itself. Now, however, the crude sap undergoes a wonderful change; but before attempting to explain to you the nature of this change which is carried on in the leaves, I must briefly describe the spaces which lie between the veins, as

* These salts are phosphates, carbonates, sulphates, nitrates, silicates, and chlorides of lime, potash, soda, ammonia, magnesia, and iron. (See table of salts, page 48.)

they appear when magnified a few hundred times under a **microscope.**

211. A leaf is covered on both sides with a thin skin, which is full of exceedingly small holes, or **breathing pores.** Between the upper and under skins, the leaf consists of little **cells full of juice.** The cells and pores also contain minute grains of **chlorophyll,** which is the name given to the green colouring-matter of leaves.

212. Through the pores the leaves breathe *in* the carbonic acid gas from the surrounding atmosphere ; and the **chlorophyll grains,** under the influence of **sunlight,** in some wonderful way, cause the **carbon** and **oxygen** of the carbonic acid to **disunite.** The leaves **retain the carbon** as plant-food, but allow the **oxygen to pass out** again into the air (par. 119). This decomposition of carbonic acid can *only* take place under the influence of sunlight, and therefore only goes on in the daytime.

213. So you see, the leaves are the meeting-places of the soil-food and air-food ; and they meet here for the special purpose of combining together. The **carbon** forsakes the company of the oxygen for that of the **hydrogen** and **oxygen** of the water in the crude sap, and forms with them the non-nitrogenous substances **starch, gum,** and **sugar.** And these, again, by union with the **nitrogen,** also contained in the crude sap, produce the **albuminoids** or nitrogenous substances. In addition to the starch and sugar just mentioned, the **hydrogen, oxygen,** and **carbon** combine to form the various **acids** that give the sourness to lemons, rhubarb, apples, grapes, and other fruits ; and also to form the **fats** which occur *largely* in those plants which produce oil-seeds, and in a *lesser* degree in all other cultivated plants. **A little ammonia** *is also absorbed from the air by leaves ;* and this adds to the supply of nitrogen already brought into the leaves by the crude sap, for the formation of the albuminoids.

LESSON XLIV.—GROWTH—OFFICE OF LEAVES.—II.

214. But besides *drawing in gases*, the leaf pores (and especially those on the under side of the leaf) **breathe out water vapour** in the daytime, and more rapidly in strong sunlight. A sunflower gave off 22 ounces of water in 24 hours ; and a maize plant in 105 days exhaled no less than 36 times its own weight of water.* Imagine, therefore, what must be the enormous amount of water given off by evaporation from a whole field of a leafy crop such as beans, clover, or turnips. No wonder, then, that the soil of a field bearing a crop is always drier than that of a bare field.

215. But this enormous loss of water by **evaporation** is the **main cause of the crude sap coming up** from the roots, through the stem, to the leaves. It rises by capillary attraction (par. 53), just as the oil in a lamp rises in the wick as fast as it is burned away at the top. It may also occur to you that the water which is used to supply the hydrogen and oxygen for the formation of the organic substances that are to make the new solid matter of the growing plant, will also cause a further loss of water, in addition to that by evaporation.

216. You will now have some idea of the great importance of leaves, as organs of plant nutrition ; for you have seen that **they absorb carbon**, far more of which is required by the plant than of any other element ; that by exhaling water, **they cause the rise of the sap** which conveys all other kinds of plant-food from the soil ; and that **they organise**—that is, arrange and prepare—the different crude **feeding materials** into substances that can at once form a part of the solid tissue of the plant itself. In other words, **leaves** are largely the **collectors** of plant-food, and are at the same time the **factories** where plant-foods are prepared.

217. If you were to place all the leaves of a full-grown plant flat on the floor, and touching each other, you would be surprised

* *How Crops Grow*, page 275 (Macmillan & Co.).

at the large area they would cover. The sunflower mentioned above had a total leaf area of 39 square feet; but you will not wonder at the reason of this, now that you are acquainted with the importance of their work. How necessary it is for the welfare of a plant that the leaves should be in a healthy, well-developed condition!

218. The new sap, instead of simply being a weak solution of certain salts, as the crude sap was, has lost a great deal of its water, and contains nitrogenous and non-nitrogenous substances, as well as mineral salts, for the making of the new parts of the plant that are formed in its growth. This sap is named the **elaborated sap**, to distinguish it from the *crude sap*. The word 'elaborated' means 'produced *out* of *labour*,' and the sap is so named, because it is the *result* of the *work* of the leaves.

219. Before following this sap in its further course through the plant, I should like just to say a word to you about the chlorophyll or leaf-green. Many experimenters have succeeded in growing and bringing to perfection oats and maize in bottles containing solutions of salts, composed of nitrogen and the essential ash ingredients. This mode of cultivation is called *water-culture;* and by it, these persons have made several interesting discoveries about the ash ingredients; one of which is, that if **iron** is entirely **absent** from the solution, **no chlorophyll** is formed in the leaves, consequently the **leaves** are white, and **unable to decompose the carbonic acid** of the air. Growth is at once checked for want of carbon food, and the plant gradually dies. And yet, strange to say, if only one drop of iron in solution be added before the plant dies, chlorophyll is formed, the leaves soon become green, and growth proceeds. This remarkable discovery proves, that although very little iron is sufficient, yet *some* is really essential to plant life and growth.

LESSON XLV.—GROWTH—SAP MOVEMENTS—I.

220. The elaborated sap moves to all parts of the plant, partly by soaking from cell to cell, and partly along the ducts. It forms the juice of the young cells, and the sugar and starch which it contains are easily converted into the **cellulose**, or cell coverings, which is really the tissue and woody-fibre of the plant. If the leaves are not full grown, some of it remains in them to form the new portion that is yet to be produced. Some of it goes down to the roots to increase the size of those already in existence, and to furnish the material for the growth of new feeding-roots. Also in its journey downwards, some remains to increase the bulk of the stem. And much of it moves upwards to supply the requirements of the buds from which the new portion of the stem, the new leaves, the blossoms, and the fruit or seed will spring.

221. But the order of the sap movements in these different directions is not the same in all plants. It depends entirely upon the number of seasons a plant can live. We can divide plants, according to length of life, into three classes: *First*, Those that do all their growing, and produce and ripen their seed, in *one* year, and then die. *Second*, Those that take *two* years to grow and ripen their seed before they die. And *third*, Those that live through *a number* of years, and produce seed each year. Those of the first-mentioned class are termed **annuals**; those of the second, **biennials**; and those of the third, **perennials**. For instance, the grain crops and beans and peas are annuals; they ripen in one year, and then die, and require to be sown again for the next year. Root-crops, and most clovers, are biennials; they produce their seed at the end of the second season, and then die. And all kinds of trees, and most of our meadow-grasses, are perennials; they will produce fruit or seed each year, and yet continue to live through a number of years.

222. Let us take a wheat plant as a type of all **annuals**; a

turnip and a clover plant as examples of biennials; and an apple-tree as a specimen of a perennial. By following the movements of the elaborated sap in each of these instances, we shall get a fair insight of its workings in *all* our cultivated plants.

223. From the leaves of the young wheat plant, the sap goes into the stem, and thence downwards to the roots, and upwards into the bud, supplying it with material for the formation of the unfolding leaves and growing stalk. Before long the ear appears, and growth now proceeds at its most rapid rate, till the plant is in full bloom. And now all the energies of the plant are devoted to the formation of the seed; the sap completely forsakes the leaves, and as a consequence, they fade and die; the roots cease to absorb food from the soil; and all the **sap in the stem rises into the ear to form the seeds.** The *soluble* non-nitrogenous substances (such as sugar) and the *soluble* albuminoids, which together compose the milky substance in the unripe grain, become changed, by the ripening influence of the sun, respectively into *insoluble* starch and gluten, such as we obtained from the wheaten flour (pars. 199 and 200).

224. And now that the plant has completed its work, and the sap has all been changed into solid matter, let us see how the substances are shared between the seed and the rest of the plant. The **seed contains** by far the greater portion of the **nitrogen** and **phosphoric acid**; while the **straw contains** the greater part of all the **mineral substances**, *except* the phosphoric acid. The carbon from the air, and the hydrogen and oxygen of the water, have formed the whole of the cellulose of which the straw (minus the ash) consists; and of the starch, of which nearly six-sevenths of the seed is composed.

LESSON XLVI.—GROWTH—SAP MOVEMENTS—II.

225. We now turn to the turnip to teach us something of the sap movements in **biennial roots**—turnips, swedes, mangels, beets, parsnips, carrots, &c. The crude sap and carbon are elaborated in the leaves much in the same way as they were in the wheat plant; but on leaving the leaves, the whole of the elaborated sap moves downwards to the root. The **work of the first year** seems to be, to gather as rapidly as possible all the crude plant-food from the soil and air, and to **store it in the root** in the elaborated forms of **non-nitrogenous and nitrogenous substances and salts for the second year's work.** Consequently there is a great enlargement of the tap-root.

226. In the second year of the turnip's life, it throws up the flower-stem; the many branches of which bear a fine show of yellow bloom, and afterwards the seed. The **root supplies the materials for the second year's growth**; and in so doing, exhausts itself. In the formation and ripening of the seed, the same changes take place as in the formation and ripening of grain. But as the farmer grows the turnip for food and *not* for seed, he secures its roots at the end of the first year, when it has gathered its store of food from the soil and air.

227. In the clover plant, a great deal of the elaborated sap of the first season's production is stored in the stem for the second year's growth. But as the leaves of the clover do not die at the end of the first year, but continue green through the winter, it cannot be said that growth is quite suspended. Still, very little progress is made during the winter; but in spring the elaborated sap already in the stem rises quickly, and causes a rapid development of stem and new leaves. The roots and leaves, too, rapidly collect crude food, which is as quickly prepared for the formation of the seed. But here again the farmer's object is to secure food for his cattle, and *not* seed; so **he cuts it** while it is **in full bloom**, when the **leaves and stem contain the greatest amount of nitrogenous and non-nitrogenous substances**, and

before any of them have been utilised for the formation of the seed.

228. The apple-tree will next engage our attention, and it will teach us something of the movements of the elaborated sap in perennial plants. This sap moves from the leaves to all parts of the tree to enlarge the roots, trunk, and branches, and to form the fruit; but after the fruit has been produced, the whole of the elaborated sap that is in the leaves moves into the trunk, where the soluble substances are stored in an *insoluble* condition between the wood and the bark till the following spring. The leaves thus deprived, as it were, of their life-blood, die, and fall to the ground. The spring sun calls the tree into life again by making soluble once more the insoluble substances which were deposited in the stem, and thereby enabling them to rise and make the buds burst into new leaves.

229. Perhaps you know that a great deal of sugar is obtained in Canada from the maple-tree. As it is a striking illustration of what I have just been telling you, I will explain the practice briefly to you. In the fall of the year, much of the non-nitrogenous matter of the sap is deposited inside the bark as *starch;* it would therefore be useless to pierce the maple-tree in the winter for the purpose of obtaining *sugar;* but in spring this starch is converted into sugar, ready to move upwards to feed the buds, and therefore at this time the tree is pierced, and the sap, rich in sugar, trickles out, and is collected, and prepared for household purposes.

230. Some annuals may be made to assume the character of perennials by cutting off their blossoms each time they appear, and thereby preventing the exhaustion, and consequent death of the plant, which occurs when the seed is allowed to form and mature. In this way a mignonette plant (which in our climate is an annual) may be made to grow into a little shrub, and to produce a succession of its sweet-scented blossoms for many years.

LESSON XLVII.—FARM CROPS.

231. **A knowledge of plant-life**, such as I have endeavoured to impart to you in the last few lessons, is of great practical use to the farmer. It teaches him the **necessity** of procuring **a fine moist bed** for his seed, and also the need of **shallow sowing** in a close clay soil that will not readily admit air. From it he learns the importance of encouraging a **healthy leaf development**, and that **blooming time is the time to cut his grass or clover in** order to secure them in their most nutritious condition. It also shows him the **value of the various parts** of a plant **for both feeding and manurial purposes.**

232. But when the farmer has carefully prepared his soil, by cultivation and manuring, to receive the seed, it is still necessary, if he would be successful, that he should sow *good seed;* and that he should only grow crops that are adapted to the soil and climate of his farm, because these only will come to perfection and give a profitable yield. I intend, therefore, in the following lessons to give you some account of our common farm crops, and the conditions under which they are most successfully grown.

233. It is well known that well-ripened *new* seed is more active and productive than older seed. The seeds of some plants actually lose their power of growing if kept longer than the next season ; others retain their vitality much longer ; but all, sooner or later, become quite unable to germinate. Dishonest seedsmen frequently mix their stock of worthless old seed with the new, so as to sustain no loss by it, and at the same time, not to be easily found out in the fraud they are practising on their customers.

234. But there is another important consideration in choosing seed for sowing, namely, its **pedigree.** By this is meant a certain excellency of character, which has been established by a careful selection, year after year, of seeds possessing this excellency, and by a careful cultivation of them in a fertile and suitable soil,

and in a favourable climate. In fact, seed of **good pedigree** simply means **well-bred seed.** This is the way in which the best varieties of our several farm crops have been produced ; and it is also the way in which our **cultivated crops** were first **obtained from wild plants.**

235. There is a wild grass (*Ægilops ovata*) which grows along the French and Italian shores of the Mediterranean, which, when cultivated in a fertile soil for a few years—the best seed being selected each year for sowing the next—produces seed resembling wheat-grains. Wheat has been cultivated for so many thousands of years, that it cannot be positively stated that this particular grass was the original parent of wheat, but there is no doubt that all our varieties of corn were derived from wild grasses such as this sea-shore grass.

236. Again, all our cultivated plants of the turnip and cabbage tribe were derived in like manner by careful selection and cultivation from one or more species of wild Brassica, which have spindly woody roots, bitter leaves, and both woody and bitter stems, quite unlike the large roots or heads of our cultivated turnips and cabbages.

237. Our potatoes too, with their large and mealy tubers, are the offspring of the wild potato, which grows on the coast of Chili in South America, with only tiny bitter tubers. By selection, and good cultivation in more fertile soils and colder climates, our present varieties have been produced ; but if they were removed to the Chilian coast again, they would soon degenerate into their former worthless condition.

238. Beets, mangels, carrots, parsnips, onions, and clovers—all have been similarly derived from wild plants, generally of little or no value in their uncultivated state.

239. I have said that some crops flourish better on certain soils, and in certain climes, than others. And it is to the farmer's profit to cultivate only those that are adapted to his soil, and will thrive under the climate of the place in which his farm is situated. It is a merciful and striking arrangement of Providence, that **some nutritious food** or other, for animals, **can be grown on almost any soil,** and in almost any climate. The reindeer of the Arctic regions finds sufficient nourishment for its own support and for that of its Lapland master, in the lichen which

grows beneath the snow. The Scotch peasant can grow the most nutritious oats in a climate of low summer temperature that would fail to ripen wheat. The North German can grow good crops of nutritious rye and mealy potatoes on poor shifting sands that would fail to grow other crops profitably. And I have seen excellent crops of nutritious sainfoin (a plant between the clover and vetch) profitably grown for sheep-feeding, for several years in succession, on a poor chalk farm on the Chiltern Hills, where other crops had repeatedly failed to pay the working expenses.

LESSON XLVIII.—WHEAT.

240. We may divide our farm crops into three classes, namely, **grasses, legumes,** and **roots.** We have already spoken of these same three divisions as the **silica, lime,** and **potash** classes (par. 138). The **grasses** may again be divided into the **cereals** or grain-producers—as wheat, barley, and oats; and the **fodder grasses**—such as meadow-grass and rye-grass. In like manner, the **legumes** may be divided into those that are grown **for their seed**—as beans and peas, and those that are grown **for fodder**—such as clovers, vetches, lucerne, and sainfoin. The **roots** include turnips, mangels, potatoes, carrots, and parsnips. There are also **other crops**—as cabbage, rape, and kohl-rabi, which, though belonging to the turnip tribe by nature and chemical constitution, are grown for their stems and leaves only, like clovers and vetches; they therefore form a link between the legumes and roots.

241. The first crop I shall speak of is **wheat.** The land best adapted for the growth of this important crop is a fertile **clay, or clay loam.** These soils contain an abundance of silicate of alumina, from which the wheat can obtain, without much difficulty, the silica upon which it so largely feeds (par. 137). If these soils be well cultivated and manured, wheat can be grown upon them *continuously* with success.

242. Wheat is generally **sown in autumn,** and makes considerable growth before winter sets in. It is hardy enough to stand

the cold of a severe winter, particularly if protected by a covering of snow. There is a variety which is sown in spring; but spring-wheat is seldom so successful in its growth as winter-wheat. The roots of winter-wheat strike down so deeply into the soil, that they generally reach as far below the surface of the ground as the ear does above. For this reason, wheat is not easily affected by a drought on firm land; in fact, it likes a dry summer and hot ripening time. The best English wheat is grown in Kent and the other south-eastern and eastern counties, which have drier summers than the northern and western counties. And the bright summer weather of Italy produces wheat rich in gluten, and therefore peculiarly suitable for the preparation of Italian macaroni. The Scottish summer is too wet and cool to ripen wheat well. In spring, the young wheat is generally rolled to make the land firm, as it thrives best in a firm soil.

243. Wheat should be cut soon after the upper portion of the straw turns yellow, which will be about a fortnight before the grain is quite ripe. The grains are then heaviest, and contain the largest proportions of starch and gluten for grinding into flour. If wheat be allowed to stand till it is 'dead ripe,' some of the starch changes to woody-fibre, thereby giving the grains a thicker skin. It is then a better protected *seed*, but less suitable for the miller, for he likes a grain which contains the largest proportion of flour and the least proportion of bran.

244. The best manures for wheat are nitrogenous and phosphatic manures *together*. On fertile soils, nitrogenous manures *alone* have a tendency to encourage a luxuriant grassy growth, instead of a large yield of grain; and especially is this the case in a wet season. This is partly controlled by the use of superphosphate with the nitrogen, and more completely by the use of salt (par. 173). Common salt, like the acids, renders soluble many of the mineral substances in the soil, such as the phosphates, and by so doing, enables the plant to mature its seed sooner than it otherwise would.

LESSON XLIX.—BARLEY.

245. Light soils containing much lime are generally considered the best for barley. The reason of this is, that these are the soils which produce the best barley for *malting*. And this is the purpose for which it is mainly grown in this country. Malting barley, too, brings the farmer a higher price than any other kind. But it does not at all follow that other soils will not produce as large a crop, and of as good quality, for other purposes; in fact, a much larger yield of better feeding barley can be grown on fertile clays or clay loams.

246. But let us see wherein lies the difference between malting and feeding barley. In growing barley for malt, the aim is to produce a grain which shall contain the largest possible proportion of starch, and the smallest possible proportion of nitrogenous matter; for it is the starch that changes to sugar, and the sugar that afterwards produces the alcohol or spirit of the beer. But highly nitrogenous and not fully ripened barleys produce, in addition to diastase, other ferments which injuriously affect the preparation of malt liquors. And yet, this growth of barley is much better than malting barley for feeding purposes, because it is richer in nitrogenous or lean-making substances. It is also better for seed than the highly developed starch grains that are so suitable for malting. The cause of the unfruitfulness of the best grinding wheat and malting barley is in both cases the same, namely, a weakened cellular system, due to a forced development of starch.

247. Fertile clays and firm loams retain moisture and forcing (nitrogenous) manures much better than light loams and chalky soils, and hence encourage a coarser growth of barley. The result is, therefore, a much larger crop of straw, and also a larger total yield of grain, less highly developed, but very nutritious, and of a hardy character. On the other hand, chalky soils and sandy loams discourage a grassy growth, and cause the ears to

appear earlier; and the whole energies of the plant to be spent in producing fewer ears of finely developed grain, rich in starch, thin-skinned, and less nitrogenous. A good sample of malting barley may also be obtained from a fertile clay loam, if it be made to follow wheat. The growth of a wheat crop first, will have reduced the forcing power of the soil, and consequently the grassy growth of the barley will be prevented.

248. Barley matures in a much shorter time than wheat, and can therefore be grown very much farther to the north than wheat, in countries which enjoy only short summers. It requires to be sown in spring, at a dry time; a wet or rather muddy seed-bed is sure to lessen the yield of barley considerably.

249. It is a shallow-rooted crop, and for this reason, and also because it is generally grown on light soils that do not retain moisture well, it suffers seriously from a drought.

250. Barley should not be cut before it is dead ripe if it be intended for malting; for if the albuminoids be not fully matured, the objectionable fermentation which I have referred to (par. 246) may afterwards take place in the preparation of malt liquors. Farmers frequently suffer loss, from the breaking off of the ears of this very ripe barley, in the cutting.

251. The best manures for barley, as for all grasses, are those rich in nitrogen and phosphoric acid; hence nitrate of soda and superphosphate of lime act very beneficially on a barley crop.

LESSON L.—OATS.

252. The oat is one of the hardiest plants that is cultivated; it can be successfully grown on poor clays, on peaty soils, and even on marshy and undrained land; it will thrive on the Highland farms of Scotland at a great height above the sea-level; and will ripen in a damp climate and at a low summer temperature. These are very unfavourable conditions for the growth of either wheat or barley, and therefore *they* give place

to *oats* when these conditions prevail. You must not suppose, however, that these are the conditions under which oats flourish best; on the contrary, the oat delights in a well-drained, fertile clay, and in a pleasant climate, if not too dry. Still, it struggles hard and produces fair crops where wheat or barley would fail; but on a fertile, well-drained, and well-cultivated clay or firm loam, with a moist and cloudy summer, it will yield nearly twice the quantity of grain per acre that wheat will. The average yield of wheat per acre on suitable land is four quarters (eight bushels to the quarter), of barley five quarters, and of oats six quarters; and under exceptionally favourable conditions, oats have yielded considerably more than ten quarters to the acre.

253. But in addition to being a **large cropper**, it is a most **nutritious** grain. When separated from the husk, which, unlike the chaff of wheat, is closely attached to the grain, the oat contains a greater proportion of nitrogenous or **flesh-forming** matter than either wheat or barley; and as much as a tenth of its non-nitrogenous (fat-forming) matter exists in the valuable form of **fat**, whereas in wheat and barley it is nearly all in the form of starch. For these reasons, oatmeal is one of the most strengthening and fattening vegetable foods that can be eaten, and is particularly well adapted for growing children, and as a diet for somewhat cold climates like the Scotch Highlands.

254. The nitrogenous part of wheat is called gluten (par. 199), and wheat contains more of this substance than any other grain. And this is why **wheaten flour** makes the **best bread.** The gluten gives the peculiar stickiness to dough which enables it to stretch without breaking when blown into bubbles by the carbonic acid gas produced by the action of the yeast on the sugar of the flour. And so, much of the gas is prevented from escaping, and we get bread full of tiny holes, or as it is generally called, light or crummy bread. Barley-meal is much poorer than wheaten flour in gluten, and therefore is not so suitable for bread-making. And the chief albuminoid of **oats** is more like **legumin** (par. 202) than gluten, consequently oatmeal is quite unfit for loaf-making, though it is frequently made into thin cakes.

255. There are **many varieties of oats**, some white and some black, some early and some late; some requiring to be sown in autumn, others in spring; some suitable for high-lying districts,

others not, because liable to shed their seeds in high winds; some suitable for peaty and marshy soils, some for poor clays, and others for better soils.

256. You must have noticed that oats do not grow in compact ears like wheat and barley, but hang, two or three seeds together, on a cluster of little branches. In some varieties, these little branches hang all *around* the flower-stem, at a considerable distance apart; while in others, these seed branches hang closely together, and all on *one side* of the stem. On account of these peculiarities of growth, the **oat grains** on the same stem **do not all ripen together**; the earlier ones, therefore, have to wait for the later ones, so that oats cannot be cut more than a week before they are dead ripe.

257. **Oat straw** is much **better fodder** than wheat straw, and if the growth has been grassy, and the seed development poor, it is very much better than barley straw also.

258. The severer climate of Scotland produces **hardy seed**, which proves very productive when planted in the richer soils and milder climate of England. Nitrogenous manures make a more marked improvement to an oat crop than to either wheat or barley.

LESSON LI.—MEADOW-GRASS AND MEADOW-HAY.

259. Grass-land is either **pasture or meadow.** That which is always used exclusively as grazing ground is called pasture, and that which is occasionally mown for hay is termed meadow. Most farms have some grass-land, but some few have none, while others consist almost entirely of grass-land. That part of a farm that is regularly **under the plough**, and actively cultivated, is called the **arable or tillage** portion. There are two very different kinds of land that are used for grazing purposes. First, the **hilly districts**, and especially the chalk downs, that are too poor to pay for cultivation as arable lands; these produce short sweet herbage, upon which large numbers of **sheep are fed.** And next, the **fertile plains** in the **damper districts** of our island, such as the

west of England, and the banks of the rivers, where luxuriant crops of rich grass **fatten** our beef, and supply us with **milk** and **butter** and **cheese**. Dairy-farms prevail in these districts. The **drier parts**, that are better adapted for the perfect ripening of corn, are chiefly laid out in **arable farms**. Many of our pastures have never been anything but pastures for hundreds of years.

260. The first great aim in the management of meadow-land should be to secure a nutritious variety of grasses, and this cannot be attained if the soil be too wet and badly drained, or too poor. Some grasses are of little value as food, and are disliked by cattle. A meadow that will not allow water to pass easily downwards, will produce rushes, and coarse aquatic grasses of an innutritious and sour character. **Good drainage** will soon cause these kinds to die out, and more **nutritious grasses** to spring up; and a dressing of **lime** or gypsum (sulphate of lime) will destroy sorrel and sour herbage, and encourage the growth of **clovers**. Manuring with good **farmyard manure** will make mosses, daisies, and other plants that are always a sign of poverty, disappear, and cause a luxuriant growth of the **better meadow-grasses**. When a poor meadow has been well drained and manured, a good start should be given it by sowing seeds of the best grasses and perennial clovers.

261. The same manures which are beneficial to the cereals are also best for *meadow*-grasses. **Phosphatic manures** must be applied to supply the place of the phosphoric acid that is annually removed from pastures, in the bones and milk of the animals fed upon them. And **nitrogenous manures** may be applied more liberally than to the cereal grasses, because luxuriance of stem and leaf is just what the farmer aims to get in his meadows; but in the cereals, as I have before explained, the luxuriance attained in the straw, by the use of nitrates, is often at the expense of the ear, and therefore needs control.

262. **Rolling in spring**, after the hollowing influence of the winter's frost, improves grass-land, and prevents in some measure the ravages of insects among the roots, by closing the numerous holes. **Chain or bush harrowing**, after manuring in spring, also improves it by combing the manure in closer to the roots, and by preventing the surface from becoming hide-bound.

263. The young juicy grass of the month of May is richer in nitrogenous substances, and contains less indigestible woody-fibre (being young and tender) than older grass, and is therefore much more nutritious. But as most of our meadow-grasses bloom in May, June, and July, the middle of June is generally the best time for the farmer to cut his grass for hay. You have already learned (par. 227) that at blooming time the stem and leaves contain the largest amount of soluble nitrogenous and non-nitrogenous substances; and that later, much of the soluble non-nitrogenous matter changes to the indigestible woody-fibre of the stem, while the rest, with the nitrogenous matter, goes up to form the seed. So that if the farmer lets his grass ripen, the seed sheds, and he loses all the flesh-forming substances, and has little else than indigestible woody-fibre left.

264. For hay-making, the farmer likes warm drying winds rather than a scorching sun; the grass then loses its moisture thoroughly, without at the same time losing its sweetness and fragrance. If grass takes much rain after it has been partly dried, a good deal of the soluble nitrogenous and non-nitrogenous substances will be washed out, and the hay will be of much less feeding value. Much of these substances will also be lost if the hay be carried before it is sufficiently dried; the loss will then be due to the escape of gases produced by the fermentation which will take place in the rick. The heat produced by this fermentation is sometimes sufficient to set the rick on fire, and oftener, to char much of the hay in the centre, and make it useless. You will have some idea of the amount of water that has to be dried out of grass, in order to make it into hay, when I tell you, that five tons of grass from about an acre of land, only makes one and a half tons of hay.

265. Rye-grass, and Italian rye-grass, are often very profitably grown for green fodder on light soils, as arable crops, taking their place in the ordinary rotation. They are very tall grasses, and yield large crops, and are sometimes allowed to remain down for more than a year. If Italian rye-grass be regularly irrigated—that is, flooded at regular intervals, on well-drained land—it will yield as many as six crops a year.

LESSON LII.—BEANS AND PEAS.

266. We now come to the second great class of farm plants, the legumes or pod-bearers. They all contain the albuminoid **legumin**, a nitrogenous substance closely resembling the **curd** or cheesy portion (casein) of milk. They do not as closely resemble each other in appearance as the members of the grass family do, but they are very much alike in chemical composition; and when their **blooms** are closely examined, they are all found to be formed on the type of the **pea-blossom**, and all contain their seeds in **pods**. Beans, peas, and clovers, so unlike each other in general appearance, closely resemble each other in the particulars I have just mentioned.

267. You are already aware that the **grasses** take very **little lime** from the soil, and a great **deal of silica**. The **leguminous plants**, on the other hand, take a great **deal of lime**, and **scarcely any silica**. They also require more than **twice as much potash and nitrogen** as the cereals. Being so highly nitrogenous, they are all good **flesh-formers**, and therefore **excellent foods for young, or milking animals, and for working stock**; but they require good digestion.

268. You have all seen a field of beans growing, and enjoyed the sweet scent of the bean-blossoms in early summer. They and the blossoms of other legumes are the delight of the bees too, for from them they gather the greater part of their honey. It is about beans that I shall first speak. Not the broad beans of our gardens, but **field-beans**, often called horse-beans. They may be divided into two kinds—**winter beans**, which are planted in autumn; and **summer beans**, which are planted in early spring. The winter variety is the greater favourite with good farmers, because it generally yields a better crop, and more frequently escapes the attack of the 'black dolphin' fly than the summer kind. This bean blight always attacks the top of the plant first, and by degrees spreads downwards, and so perforates the leaves

as to prevent them doing their work; and consequently the further fruiting of the plant is stopped. The general remedy is, to cut all the tops off as soon as it appears. Winter beans are not able to stand the frosts of a very *severe* winter.

269. The bean only thrives on **well-drained fertile clays and firm loams**, and in a **somewhat damp climate**; it is therefore mainly cultivated on the stronger lands of the west and north of England and in Scotland. The average yield of beans on bean land is much the same as that of wheat, namely, four quarters per acre. Beans cannot be grown on the same land continuously as wheat and barley can; the land becomes what is called '*bean sick*.'

270. The pea is the only leguminous plant in addition to the bean that is grown for its seed. And the same conditions of soil and climate that are favourable to the cultivation of the bean, also favour a luxuriant growth of the pea.

271. **Peas** are shallow-rooted, and therefore **surface-feeders**. They are sown in early spring, and are generally cut before the white grains, thus forming the first fruits of corn harvest.

The straw of well-harvested beans and peas is valuable as fodder; like all straws, they consist largely of crude fibre which is indigestible, but they are far more nutritious than the cereal straws, and are quite equal to poor hay.

272. Kainit and gypsum (sulphate of lime) are suitable artificial manures for leguminous crops; you would expect that they would be, from potash and lime being the chief ash constituents of these crops; but you will probably say: 'Do not nitrogenous manures also very greatly benefit these crops, for you told us that they contain more than twice as much nitrogen as the cereals?' Well, as a matter of fact, nitrogenous manures do *not* produce the same marked effects on leguminous crops as upon the grasses; and the reason probably is, that the cereals can only feed on nitrogen that is in the form of a nitrate in the soil; while leguminous crops—the roots of many of them of a very searching character—can feed upon nitrogen in other more common and less acceptable forms; and having large leaf areas, probably also absorb ammonia from the air. Farmyard manure, however, is the one more generally applied to beans and other legumes, and with good results.

LESSON LIII.—LEGUMINOUS FODDER CROPS—VETCHES, CLOVERS, SAINFOIN, AND LUCERNE.

273. The farm crop that most nearly resembles the pea in its habits of growth is the **vetch** or tare. It is cultivated as a fodder crop for horses, cows, and sheep, to be eaten when in bloom. It is mown and carried off the land little by little as required, for horses and cows; but sheep are penned on it in small folds. Both winter and spring varieties are cultivated; and the former is an especially valuable crop, because it comes in as a very abundant and nutritious food-supply at the end of spring, when the winter stores of roots and hay are generally exhausted. The **vetch** is a particularly suitable crop **for clay farms** and **limy (calcareous) loams.**

274. The most valuable leguminous crop, however, that the farmer grows, is **clover.** It not only furnishes him with a large quantity of **very nutritious cattle food** for both summer and winter use, but **improves the soil** in a wonderful way for the growth of white corn. There are many varieties of clover, but the most important one, and the one most generally cultivated as a distinct crop, is the **common red clover,** with which you must all be familiar. It is one of the **deepest rooted** of all crops, and flourishes best in a **deep, light soil, which contains much lime;** but it can also be profitably cultivated on all except very wet soils.

275. Clover is sown in spring, sometimes among the young wheat; but generally among the young barley, on farms where barley is grown. As soon as the corn is cut and carried in autumn, the young clover should receive a good top-dressing of well-rotted farmyard manure; this will give it a good start before winter, and insure a good crop of hay in the following June. If kainit has previously been mixed with the manure (par. 181), so much the better for the clover.

276. **In June, while it is in full bloom, the clover is cut for hay.** You will remember what I said about the best weather for

making meadow-hay (par. 264); in the case of clover, it is even more necessary that the sun should not be too scorching, for if it be, the leaves will become so brittle as to break off in the raking and carrying, and so will be lost as food.

277. After the removal of this hay crop, the clover again shoots out, and in about two months is in bloom a second time, and ready to be cut for another lot of hay. But on sheep-farms this second, or **'aftermath' crop**, as it is called, is **fed off by the sheep**, which are penned on it in small folds day by day till it is all eaten. In this way the ground gets a thorough manuring for the wheat crop which will follow.

278. Sometimes the clover stubble is allowed to remain for hay another year; but land refuses to produce clover for many years together. Farmers say the **land becomes 'clover sick,'** which probably means that the deep subsoil, which is the feeding-ground of the clover, becomes exhausted of clover food. And this 'sickness' comes on the sooner if the subsoil is in a bad condition for the roots to search easily for food—undrained, or hard; or if sheep are allowed to feed on the *young* clover plants soon after the corn has been removed, and before they have stood the winter. As a rule, however, the clover stubble is ploughed up for wheat after the two crops of the one year have been obtained.

279. The property that the legumes possess, of collecting nitrogen from the soil, and feeding on it in almost any form, and of absorbing it as ammonia from the atmosphere, belongs to clover in a marked degree; its numerous and deeply searching roots, and its leafy character, greatly help it in this work of finding and using the various compounds of nitrogen, which occur in the soil and air. I cannot give you a better idea of **the large amount of nitrogen that a clover crop gathers** than by stating the fact, that about four times as much nitrogen is contained in the two ordinary clover crops of the one year as would be contained in an ordinary crop of wheat grown on the same land; and yet there still remains in the roots, stubble, and fallen leaves of the clover, far more nitrogen than can be made use of by the wheat crop which will follow.

LESSON LIV.—LEGUMINOUS FODDER CROPS —*Continued.*

280. The growth of clover improves the texture of the land in a way in which no labour could do it. To a light soil, the decay of the roots and stubble adds large quantities of humus, which greatly alters its character and enables it the better to retain moisture and manure. The clover also feeds upon the plant-food in the soil, and in the manure supplied to it, and retains it in its roots and stubble from being washed out of the soil, as it otherwise would be; and as the roots slowly decay, the plant-food is set free, and the corn crop gets a regular and continuous supply through the whole period of its growth. Again, sheep are always kept on light soils, where clover thrives best; and by being penned on the aftermath crop, they deposit a rich coating of unfermented manure in small bulk, in the form of their dung and urine, and at the same time tread the ground well. Now, the binding power of the roots, and the treading of the sheep, both help to give a firmness to a light soil, which adapts it for wheat cultivation; and the plant-food contained in the roots and stubble of the clover and in the fresh dung of the sheep enriches the soil in a lasting way for wheat, without at the same time rendering more open a soil, which is already *naturally* light and open. The straw of fresh farmyard manure would, on the contrary, have the bad effect of making light land still more open. So you see that the growth of clover yields an abundant and nutritious supply of food for stock, and at the same time adapts land for the profitable growth of wheat, that would otherwise be quite unfit for it.

281. Clay soils are also improved in texture by the growth of clover, for the numerous roots, which form a sort of fine network through the soil, help to separate the particles of clay, and so to counteract the tendency which these particles have of sticking together. A clay soil is thus rendered more open and free.

282. The proportion of nitrogenous to non-nitrogenous food in good clover hay is much the same as it is in good wheaten bread ; so that it is as nutritious a food for sheep and cattle as bread is for human beings.

283. There are many other varieties of clover, such as the *white or Dutch clover*, which is short in growth and mainly grown in grazing pastures ; *the yellow clover or trefoil*, in every respect a smaller variety than the common red clover ; *Alsike or Swedish clover*, which closely resembles the common clover in growth, but is better adapted for cold, moist, stiff soils ; and *crimson or French clover*, a very large kind, which being an annual and shallow-rooted, is sown on the unploughed wheat or oat stubble in early autumn, and cut as green fodder early in the following spring.

284. The only other leguminous crops that I shall describe to you are sainfoin and lucerne. In character and appearance they come between the vetch and clover.

285. **Sainfoin** will thrive on poor dry chalky soils that are too poor to be under rotation cultivation, and even yield badly under grass. Such soils will often produce two tons of sainfoin per acre. It is as nutritious as clover either in the green state or as hay, and cattle are very fond of it. The land requires to be stirred deeply, and well cleaned before it is sown ; and the yield is but small the second year unless a little clover be sown with it ; but it reaches its full growth by the third year, and then continues to yield well for about eight years. With the addition of a little oil-cake, sheep may easily be fattened on it ; and this is the most profitable way of using it, for by this mode of treatment it gets well and regularly manured. In appearance, the leaves resemble those of vetches, but the blossom is more like that of red clover.

286. **Lucerne**, either in the green state or as hay, is the most nutritious fodder that is grown on a farm ; it is even better than clover. Like sainfoin, it produces good crops for about ten years ; its roots strike to such a depth that it does not suffer from drought. In appearance, its blossom resembles that of the vetch, while its leaves are more like those of clover. It thrives best on deep, rich, light soils, but requires some care in the early stage of its growth. The land should be thoroughly cleaned

before it is sown, and the seed should be drilled in rows a foot apart in the beginning of April, so that it may be kept free from weeds for the first year; it afterwards needs little attention (par. 73), and may be cut every six or eight weeks from May to October. Cows are very fond of it, and it is almost the only green fodder except meadow-grass that can be given to dairy cows, without imparting an unpleasant flavour to the milk and butter; this makes it especially valuable. In fact, much of the excellent Normandy butter is produced entirely from lucerne.

LESSON LV.—OTHER FODDER CROPS.

287. Under this head I place all those crops that do not belong to the leguminous tribe of plants, but whose stems and leaves, like those of the legumes, are grown for cattle food. Most of them belong to the cabbage and turnip family, and in their chemical composition much more nearly approach the legumes than the grasses.

288. Foremost of these I must place **cattle cabbage**, because it is a very suitable **fallow-crop** for **clay soils**, and probably yields a greater weight of food per acre than any other crop that is grown. It lasts good through the winter till late in spring, when other green foods are scarce. This variety of cabbage grows to a great size, especially under the influence of a liberal supply of good farmyard or other nitrogenous manure; for this reason, a dressing of **nitrate of soda** has been found to have a wonderfully good effect on this crop.

289. When cultivated on clay lands, cabbage may be fed off by sheep on the ground, in summer; but in winter, when the ground is wet, this cannot be done, because the treading of the sheep would do great harm to the soil; for it is *naturally* too firm, and requires lightening up rather than treading down. Cabbage is capital green food for growing or feeding cattle, and for sheep, but is not so suitable for dairy cows, as it gives an unpleasant flavour to the milk and butter.

290. **Kohl-rabi** is a plant of the cabbage tribe of very peculiar growth; the neck of its root swelling out considerably, and forming a valuable article of food for cattle. It therefore more nearly approaches the turnip with its large root, than the cabbage with its straight stem, and so forms a sort of connecting link between them. It is a suitable crop for **clay and peaty soils**, and thrives best in a somewhat **mild climate**, such as the south of England, where it is chiefly cultivated.

291. It can be stored for winter use like swedes, and is equal to them in nutritive value; it is even to be preferred to them as a food for milking-cows, because it does not flavour the milk as unpleasantly as they do. Turnip crops of all kinds are liable to total destruction in their earliest period of growth by an insect blight; and swedes are frequently spoiled by a mildew blight in the later period of their growth. But kohl-rabi is quite **free from both insect ravages and mildew**, and therefore in this respect also can claim a superiority to the swede. Still, the weight of food contained in an ordinary crop of kohl-rabi is far less than that contained in an ordinary crop of swedes, and therefore, all things considered, it is not such an economical crop for ordinary cultivation as swedes.

292. **Rape** is another plant of the cabbage tribe, with large spreading leaves, in appearance very much like the leaves of the swede; its stem closely resembles that of the cabbage. It is generally grown for sheep; they are penned on it, and eat the leaves and upper part of the stem. It is a deep-rooted crop, and like kohl-rabi, thrives well on **heavy and peaty soils**. It is of **quick growth**, and for this reason is generally grown as a '**stolen**' or '**catch**' **crop**. A stolen crop is one which a farmer contrives to get between the ordinary crops of the rotation, to supply a pressing want of food for his stock. You can understand that such crops would have to be of quick growth in order that they may be cleared off the ground in time for the sowing of the next crop of the rotation. In driving through South Oxfordshire late in the summer of 1881, I noticed that on almost every farm the swede crop had been destroyed by the turnip 'fly' (par. 306), probably after repeated sowings; and the ground was then covered with luxuriant crops of rape. This is a common mode of employing rape—to occupy the ground where one of the turnip

crops has failed; but neither it nor cabbage can be *stored* for winter use as root-crops can. Rape is sometimes drilled between the rows of beans when they are quite tall, in order to come in quickly as sheep food after the beans are cut and carried away. Or again, it may be sown to furnish an early supply of spring food. It is also sometimes grown for the purpose of being ploughed in as a green manure (par. 160).

293. **Mustard** is another plant much used on sheep-farms for 'catch' cropping and green manuring. It is one of the quickest growing of all crops, as you will know, if you have ever grown mustard with cress in your garden. It is frequently sown after peas or early oats which are harvested before the other corn crops. Soon after harvest-work is completed, the mustard will appear in bloom, and the whole field will present a pretty bright yellow appearance.

LESSON LVI.—ROOT-CROPS—MANGEL-WURZEL, TURNIP.

294. The last class of crops that I shall invite your attention to, is the root class. It includes turnips of various kinds, the mangel-wurzel, potato, carrot, and parsnip. These are all fallow-crops (par. 87), and are therefore sown sufficiently late to allow of the ground being first thoroughly cleaned and tilled; and are then drilled in rows, far enough apart to admit of hand and horse hoeing all through the summer, in order that the soil may be *kept* clean, and as much of its dormant matter as possible made soluble by atmospheric influence (par. 68).

295. **Root-crops** are all very great feeders, and grow rapidly; and so furnish the farmer with a great bulk of juicy food for his live-stock; and by thus greedily seizing upon the plant-food of the soil as fast as it becomes soluble, they prevent the possibility of its being washed through the soil, as it would be in a light soil, on a *bare* fallow. As an illustration of the feeding power of these crops, I may say, that an ordinary turnip

crop removes from the soil more nitrogen and phosphoric acid, and *much* more potash than a leguminous crop, and two and a half times as much nitrogen, one and a half times as much phosphoric acid, and five times as much potash as a wheat crop. But inasmuch as **phosphoric acid** is the scarcest plant-food, and the one most largely carried away from the farm, in the grain crops, and milk and bones of animals, this is the substance that is found **most beneficial** as a special artificial manure for **root-crops.**

296. **They all contain a very large percentage of water**—turnips, more than ninety per cent. ; this makes them of low value as cattle foods when used alone, particularly in winter, when this water is in a very cold state. But when used with a proper proportion of other dry and nutritious food, they impart a moisture and relish to cattle diet, that makes it much more enjoyable and beneficial.

297. The **mangel-wurzel** is one of the most valuable plants of the root class, and in many respects the *most* valuable. It can be cultivated with great success on **clays and clay loams** that are quite unfit for turnips, and being a **deep-rooted** plant, it is able to thrive well in the **drier parts of England**—centre and east—and in a dry season, under which conditions, an attempt to cultivate turnips would prove a failure. It can also be grown successfully for years together on the same land, whereas turnips cannot. It yields a **larger crop** than any other kind of root, frequently as much as thirty tons per acre.

298. **Phosphatic manures** greatly improve the soil for the growth of mangels, as they do for all other root-crops ; and **nitrate of soda**, which does not greatly benefit other root-crops, has a very marked effect on mangels. In places many miles from the sea, a dressing of **common salt** also improves the mangel crop ; the reason being, that this crop removes from the soil many times more soda and chlorine than any other crop. You will remember that common salt consists of the metal sodium and non-metal chlorine (table, page 48).

299. Mangel seed should be planted in April or early in May, and the aim should be to grow a **large number of small roots**, rather than a smaller number of such enormous roots as are often now the boast of the farmer. The mangel, like all the

members of the beet-root family, **contains a great deal of sugar**; and it is a well-known fact, particularly in France and other countries where beet is very largely grown for the preparation of sugar, that the small roots contain a less proportion of water, and a larger proportion of sugar, than the larger ones. Much of the sugar in overgrown mangels is changed into indigestible woody-fibre. In order, therefore, to produce a large crop of the most nutritious mangels, the farmer should not have the young plants thinned out as much as is generally done, but should allow them to stand closer together. Over-manuring is also mischievous.

300. You will remember that I told you, that both frost and heat have the power of ripening roots, that is, of changing certain acrid non-nitrogenous substances into sugar or gum. It is seldom, however, that our summer heat is sufficient for this purpose, though it is for the ripening of many tree-fruits; frost would soon effect this change in the mangels, but would, at the same time, cause them to rot after they were stored. So the ripening has to take place in the pits in which they are stored; **the heat produced there, causes them to slowly and thoroughly ripen,** and in this change there is an increase of sugar, and loss of water by evaporation. Mangels should therefore be **stored before the frost comes, and in well-ventilated pits.**

301. **Turnips** are of many kinds, but it will be sufficient for our purpose to consider them under the three heads of early white turnips, late turnips, and Swedish turnips (swedes). **Early white turnips** accomplish their growth in the summer, and can be eaten off by sheep in the dry weather, before the autumn rains fall; hence they may be grown with advantage **on heavy soils.**

302. **Late turnips** are those most commonly grown; they are not sown before the end of May in Scotland, and the middle of June in England, and therefore give ample time for the thorough cleaning of the foulest of the fallow land. They continue their growth far into the autumn, and are **fed off by sheep during the winter** months. They are thoroughly unsuitable for clayey soils, because of the difficulty of getting a tilth, on such soils, fine enough for such small seeds; and also because either the treading of the sheep in the winter, or the

carting the turnips off for use in the sheep or cattle yard, would injuriously press down the soil. On the other hand, they are of the greatest value to **light soils**, because, by carrying on their growth far into the autumn, they seize the nitrogen that is carried into the soil by the autumn rains, and arrest for use the soluble matters of the soil, which would otherwise be washed out of such badly retentive lands by these same rains. And further, the winter folding of the sheep on the ground makes these light soils firmer, and manures them in a thorough and cheap way.

303. Turnips are surface feeders, and are consequently unable to stand much dry weather; hence they are particularly well adapted for cultivation in **moist and cloudy climates** such as those of Scotland, and of the west and north of England, and Ireland. They cannot be grown continuously on the same land as mangels can.

304. They yield largely—about twenty tons per acre—especially after the fallow has been well tilled and manured with **phosphatic manure**. If sheep are placed on them before they have undergone the ripening influence of frost, they are apt to punish them, something in the same way that unripe fruit punishes a child who eats too freely of it. Perhaps you have noticed how much sweeter parsnips taste after they have had a frost on them.

LESSON LVII.—ROOT-CROPS—SWEDE, POTATO, CARROT, PARSNIP.

305. The **Swede** is the **best root of the turnip family**, for it contains a less proportion of water, and a greater proportion of nitrogenous matter than the common turnip; and although the actual weight of produce is generally a few tons less per acre than of turnips, yet it contains about the same amount of dry matter, and this of a more nutritious kind.

306. In the cultivation of swedes, the farmer must bear in

mind one great rule, if he would be successful; and it is, to secure for the swede plant a **long and steady growth.** But from various causes this rule is often ignored, as I will show you. All turnip crops are liable to total destruction from the *turnip beetle* ('fly') soon after they appear above ground; but as soon as the plants get their rough leaves, they are safe from the attack of these insects. Now it has been found that a good dressing of superphosphate of lime has the effect of urging the young swede quickly beyond the stage at which it is attacked by the 'fly' into rough leaf, and so farmers have been induced to use this very soluble manure largely for their swede crops. The forcing power of the manure continues for some time longer, and the roots grow at a very rapid rate; but it loses this power before the swedes are properly matured, and if the summer prove very hot or dry, they are checked in their headlong course, and being delicate in constitution, through the unnaturally rapid growth that has taken place, they are attacked by the mildew blight. This **mildew** consists of nothing less than an immense number of **minute plants**, whose nature it is to root themselves on the swede plant, and **suck** the nitrogenous, non-nitrogenous, and mineral matter which they require for their growth from **the sap of the swede**; thus drawing from it, as it were, its life-blood. While the swede is in a state of steady and healthy growth, the mildew cannot establish itself; but when it is weakened by forced growth, and nearly at a standstill, it is unable to prevent the mildew germs taking root and growing. If the ground be well hoed round the roots, and a good rain sets in, the swedes may get a new start, which may enable them to overcome the mildew, but this seldom happens.

307. Forced and overgrown swedes, such as I have described, are not hardy enough to stand frost either, but turn rotten after being exposed to it; this renders them useless as a winter crop to be fed off by sheep on the ground where they were grown. Neither are they as valuable for food as the long and slowly grown ones, for they do not contain as large a proportion of dry matter, and more of the dry matter that they do contain is in the valueless form of woody fibre, into which much of the digestible non-nitrogenous matter has changed, through growth ceasing so soon. A good, soundly grown

swede will at once sink when placed in water, while an overgrown one will float like a lump of wood.

308. In order to give swedes a long and steady growth, two-year-old seed should be used ; new seed is more energetic, and often runs up to seed the first year, as if it were trying to produce its seed in one season instead of two. **The seed should be drilled as early as the end of April or beginning of May**, that it may have a long growing time before it ; and the **superphosphate should be reduced** to a less forcing and more lasting condition by admixture with about half its weight of powdered tricalcic phosphate (bone-meal or ground mineral phosphate), two or three months before being applied to the swede ground. By this method of swede cultivation, hardy nutritious roots will be produced, that will continue their growth unchecked, late into the autumn.

309. As a means of saving the young swede crop from destruction by the turnip beetle, it has been recommended to sow mustard seed among the swedes, which very quickly springs up, and being a favourite food of the beetle, keeps it from the swedes, until they get into rough leaf.

310. Good swedes store well, and are very suitable crops for **loamy soils**, even clay loams if well drained.

311. The **Potato** is in one sense the most valuable root-crop that can be grown on a farm, and in another sense it is the least valuable. As a food, it contains three times the amount of nutrition that is contained in the same weight of turnips ; and being in great demand as human food, it realises a far higher price than it would if, like turnips, it were grown as cattle food merely. But, on the other hand, by being sold off the farm, it *robs* the land of far more potash, nitrogen, and phosphoric acid than a wheat crop ; whereas all other root-crops are eaten by farm-stock, and are therefore to a very great extent returned to the land. From this it will be seen that a farmer who sends potatoes to market, should also go to market to buy manure to replace that which the potatoes have taken from his soil.

312. Potatoes may be grown on any soil, but are waxy and of bad quality for eating from clay soils, nice and mealy from light soils, and good both in quality and quantity from fertile

loams. It is therefore a suitable crop for loams, peaty soils, and sandy soils. Nearly half the ash of the potato plant consists of potash ; this is a larger proportion than is found in the ashes of any other farm plant, and this accounts for the fact, that kainit has a better marked effect as a special manure on the potato crop than on any other.

LESSON LVIII.—ROTATION OF CROPS.

313. The expression 'rotation of crops' means the order in which a series of crops are made to follow each other again and again on the same ground.

314. Three great objects are attained by growing crops in a good rotation : *First*, a larger amount of food is obtained, with less exhaustion to the land, and at a smaller expense, than can be obtained by any other means ; *secondly*, provision is made for a thorough cultivation and cleaning of the land ; and, *thirdly*, the rotation is a great convenience to the farmer, and lessens his risks. I will try to explain to you how each of these advantages is secured by a good system of rotation of crops.

315. By this time you are quite familiar with the fact that some crops draw very largely on the soil for certain ash constituents, while other crops take very little of these particular substances, but require more of other ash constituents. The cereals, for instance, take a very large quantity of silica and very little lime, while the legumes and roots take a very large quantity of lime, scarcely any silica, and a very much larger quantity of potash than the cereals, so that by growing cereals alternately with the legumes and roots, the demand for the different ash constituents is more evenly divided amongst them all. And thus a crop of beans and a crop of wheat can be grown with less exhaustion to the land, than either two crops of wheat or two crops of beans in succession ; and at the same time, the total yield of the two unlike crops will be greater than that of the two like ones.

316. Another fact you have learned is, that some crops are

subsoil feeders, and others **surface feeders**; some what we may term **choice feeders**, others **greedy feeders**. Now, you can see plainly enough that two deep greedy feeders in succession will exhaust the subsoil more than a greedy and choice one; and that two greedy surface feeders will in like manner impoverish the surface soil more than a greedy and choice one. Now, if the greedy ones are mainly *spent on the land* where they are grown, their hungry searching nature actually enables them to collect food for choice ones that will feed in the same ground. For instance, clover goes very deep, and collects and feeds on nitrogen in almost any soluble form, and in its abundance of roots stores up a supply in the subsoil for the deep-rooted wheat which may follow. Or, again, the hungry surface-feeding turnips are fed off by sheep, and so the surface soil is well filled with plant-food in a good form for the choice surface-feeding barley which will follow.

317. But besides these **differences of foods, differences of feeding grounds** and **differences of feeding powers**, crops **differ in the times** of their growth. Turnips grow all through the summer and autumn, and not only seize upon the nitric acid that is formed in the soil by the decay of manure and organic matter during the summer months, but prevent the rains of autumn washing the nitrates down beyond the reach of plants, and also secure the ammonia and nitric acid that are carried in from the atmosphere by those rains. Clover, again, by continuous growth through at least two summers and a winter, also prevents waste of nitric acid and other soluble plant-food in the soil. Barley and many other crops, on the other hand, do not commence their active growth till spring; and nearly cease to draw food from the soil by the end of June—their blooming time; consequently they derive no benefit from the nitrates produced in the soil during the months of July and August; and if they alone were grown, the nitrates and other soluble substances in the soil, together with the ammonia and nitric acid carried in by the rain, would be in a great measure washed out by the rain each autumn and winter. What a **saving of valuable plant-food** it must be then, **to let such short-lived spring and early summer feeders be preceded and followed by autumn-growing crops!**

318. From these remarks, I think you will see that the first

advantage which I stated as arising from a good rotation is one of very great importance to the farmer. But it is not left for man to settle this question alone, for nature herself teaches the necessity as well as the advantage of growing crops in rotation, in many cases. For instance, an attempt to grow clover or beans continuously on the same land, results in clover or bean 'sickness;' and the continuous growth of turnips results in poor or diseased crops.

319. In the second place I said, a good rotation provided for the thorough cultivation and cleaning of the land. In some of our early lessons (Lessons XV. and XVI.), I showed you the importance of tillage operations, both as a means of enriching the land and ridding it of weeds. And in a good rotation, the land, during one year of the course, is set apart specially for this purpose, and only such crops are then grown on it, as will not interfere with its being thoroughly stirred and cleaned. The land thus set apart for cultivation and cleaning is termed fallow land.

320. The third advantage of a good rotation is its general convenience to the farmer. By having his farm divided into as many parts as there are courses in the rotation, his prospects are not all staked on one crop; if his corn be spoiled with rain, his cattle-food may be abundant; and the same rain that spoils his hay, greatly favours the early growth of his turnips. Again, by cultivating a variety of crops that require attention at different times of the year, the labour of the farm is more evenly spread over every part of the year. In early spring, ploughing and harrowing have to be done for spring-sown corn; later, the farmer is busy, well stirring and cleaning his fallow, and sowing his earlier roots. In early summer, sheep-shearing, turnip-sowing, and haymaking will keep all hands employed; and turnip-hoeing and harvest-work of various kinds will follow close after each other till the month of September. Autumn cultivation for wheat, and the storing of roots and orchard fruits, will next have to be done; and in winter, hedging and ditching, threshing, and extra cattle-tending will still find occupation for many. This variety also tends to spread expenses over the whole year, and to give the farmer commodities for market at nearly all times.

LESSON LIX.—ROTATION FOR A LIGHT SOIL.

321. You will understand what I have been telling you about rotations much better, if I can help you to picture them in your own minds. We will first take a rotation suitable for light soils. The crops that are best adapted for such soils are **turnips, barley, and clovers.** This you have already learned; and though wheat is best grown upon naturally firm soils, yet, as I have explained to you (par. 280), the cultivation of clover will enable even light soils to produce fair crops of **wheat.**

322. The rotation I am about to mention is one in very general use in England, especially in the east, centre, and south; but is often slightly altered from its simplest form to suit the special character of the soil. It is called the **Norfolk rotation,** and is a **four-course rotation,** which means that it consists of a series of four crops, each of which comes round on the same land in proper order every four years.

323. **Light soils are cheap to work,** as they can easily be broken up by the plough with a small expenditure of horse-power, and can be reduced to a fine condition and thoroughly cleaned without much trouble. They are also much **improved by sheep treading** and **sheep manuring**; and the crops are very suitable for **sheep feeding** on the land in **folds.** You must, therefore, always associate in your mind, light soils, sheep-farms, and the Norfolk or four-course rotation. But these same soils are unable to retain moisture and soluble plant-food well, and are therefore **generally poor,** and **unable to stand drought.**

324. The following diagram is intended to represent the four divisions of a farm, cultivated on the four-course system. The rotation moves from right to left, so that No. 1 field, which is the fallow now, cropped with **turnips,** will bear **barley** next year, **clover** the following, and lastly **wheat**; after which it will come in as fallow again.

325. The first thing you will notice about this rotation, is, that **half** the farm is producing corn for market; and **half,** fodder

for sheep. Also that the fodder crops are grown alternately with the corn crops; and that the first fodder and corn crops are surface feeders, and the second, subsoil feeders. Further, that

1.	2.	3.	4.
Fallow. Turnips and Swedes.	Barley.	Clover.	Wheat.

the land undergoes a thorough tillage and cleaning every fourth year. By the frequent growth of fodder crops, and thorough tillage, the fertility of the land is kept up.

326. We will follow the rotation through. First of all, the old wheat stubble is broken up by the plough, and the land receives a good manuring with farmyard manure, and perhaps a little phosphate of lime in a very slowly soluble form. The farmyard manure should be well rotted, so that it may not take up much room in the soil, and should be applied just before sowing-time, because light soils are not retentive enough to hold the soluble matters of the manure for any great length of time before the crop is able to make use of them. By means of roller and harrow a fine tilth is obtained, the weeds are collected and burned, and the fallow is ready for swede-sowing in May, and turnip-sowing in June. All through the summer the soil is kept hoed between the rows, and thus the dormant food in the soil is gradually made soluble by the action of the rain and air, and the roots greedily feed upon the active plant-food thus produced, as well as upon the manure which was applied, and the nitrogen carried into the soil in autumn by the rain. And so you see, by cropping the fallow with roots, the active plant-food produced in the soil by fallowing is prevented from escaping from the soil.

327. In winter the sheep will consume these roots on the land, and so the plant-food that has been collected by the turnips from the various sources I have just mentioned, will be again added to the surface-soil in a slowly soluble form for the barley crop of the following year. Clover will be sown in the young barley in spring, and though at first it may take some little surface-food from the barley, its roots will soon go beyond

the roots of the barley, and feed in a lower layer of the soil. After the barley has been harvested, the clover should have a top-dressing of well-rotted farmyard manure, to give it a good start for the winter. Its roots will continue to spread and search for food all the next spring and summer, and so prevent any loss of plant-food by drainage; and after the farmer has removed the first crop of clover as hay, and penned his sheep on the aftermath, he will plough the clover stubble up in autumn for wheat. The wheat will find a supply of food at the surface, in its first stage of growth, from the sheep manure and decaying clover stubble and leaves, and in the subsoil, in its later stages, from the decay of the clover roots.

328. This rotation may be lengthened into a five or even six course, by keeping the clover down for one or two more years before ploughing it up for wheat; it would then be:

Roots,
Barley,
Clover,
Clover,
Wheat.

Or, Roots,
Barley,
Clover,
Clover,
Clover,
Wheat.

What is here called clover, would then probably be a mixture of sainfoin, white clover, perennial (not common) red clover, and trefoil, as these succeed better for a few years together than common red clover. These are profitable rotations for *poor* sheep-farms.

LESSON LX.—ROTATION FOR A CLAY SOIL.

329. We have said that **clay soils** are retentive of moisture and manure, and have the power of absorbing some little ammonia from the air ; and that they contain silica in a form which, without much difficulty, is rendered fit for the use of cereals. They are therefore either naturally more fertile than light soils, or are more capable of becoming so by liberal manuring, and are better able to stand a drought. But they **require to be well drained,** and cultivated on a system that will **tend to separate the particles** of soil, and make the land more friable in texture. For this reason root-crops cannot be fed off by sheep in winter, and the land **cannot be tilled in wet weather.** Clay soils are very **expensive to work,** for they require a great expenditure of horse-power to break them up ; and it is very **difficult to clean** them, and **reduce them to a fine condition.** Autumn cultivation by steam-power for the next summer's fallow, by which the soil is exposed in a rough condition to the crumbling influence of frost, has consequently been found of great benefit to these soils, where the climate is not too wet. As roots cannot be eaten on the land, they have to be carted off, and the manure carted back again ; this is a further expense that light lands are not subject to.

330. The crops suitable for clay soils are, **wheat, beans, oats, mangels, kohl-rabi, cabbage, clovers,** and those forage crops that can be eaten off in summer, such as **vetches, early white turnips, rape,** and **trifolium** (crimson clover, see par. 283). Clay farms generally have a large proportion of the land laid down in **permanent pasture,** partly because the soil is capable of retaining the moisture necessary for a plentiful growth of grass ; partly to save the expense of working it as arable land ; and partly also, because they are not well adapted for winter sheep-folding, and therefore must be made suitable for cattle-feeding. Hence

clay farms should always be associated in your mind with wheat-growing, and dairies or cattle-feeding.

331. The following is a good rotation for clay farms :

1.	2.	3.	4.	5.
Fallow. Vetches. Cabbages. Mangel. Rape, &c.	Wheat.	Clover.	Wheat.	Beans.

You will at once see that this is a five-course rotation, and that wheat comes after the fallow, when the land is in its most fertile condition ; it thus takes the place of the barley of a light soil. You will also observe again, the rule of alternating the cereal with leguminous or fodder crops. But by this system of cropping, *beans* are grown for market, in addition to the two wheat crops. On poor cold clays, oats frequently take the place of the second wheat crop.

332. The cleaning only takes place once in five years, consequently some of the land becomes very foul, and requires the whole of the summer to clean it thoroughly ; when this is the case, only the cleaner portion of the fallow can be cropped. On rich clays this rotation is often lengthened into a six course, by growing another crop of wheat after beans thus :

Fallow (bare or cropped),
Wheat,
Clover,
Wheat,
Beans,
Wheat.

By this course, a farmer would have two-thirds of his farm producing corn for sale each year. The beans would have to be manured, and kept as clean as possible by frequent hoeing, or the land would become so foul, that he would be unable to get his fallow clean early enough in the summer to crop it.

333. I will just point out the way in which the fallow would

be cropped. The cleanest portion of it would be ploughed up in autumn, as soon as the previous corn crop was removed, and **winter vetches** would be sown. These would be eaten off, or cut as green fodder for horses and cattle late in spring, in time for the ground to get a thorough summer's cleaning. The next cleanest portion might be cleaned, and well manured for **cabbage-planting** in spring, and kept well hoed between the rows, as long as the size of the plants allowed of its being done conveniently. A considerable portion of the fallow would be well **cleaned and manured for mangels. Kohl-rabi** might also be planted, if the farm were situated in a mild climate ; or **early white turnips**, if in a damp one. On fouler portions that took longer to clean, or even on the ground cleaned after the vetches, **rape** might be sown. And the foulest piece of all would probably have to remain a **bare fallow**. Always remember that the fallow year is the one for thorough cleaning, thorough tillage, and thorough manuring.

LESSON LXI.—ROTATION FOR LOAMS.

334. **Loams** are the most valuable of all soils because they are more retentive of moisture and manure than light soils, and are not so expensive to work as clays. Also because almost all crops can be grown on them, and they are adapted alike for sheep-farming, dairy-farming, and cattle-feeding.

335. The following, which is a **modification of the simple four-course rotation**, is an excellent one for such soils ; and I have seen farming of the most profitable kind carried on under it in Berkshire and South Oxfordshire :

1. Fallow.	2. Barley.	3. Beans.	4.
Trifolium. Vetches. Mangels. Swedes. Turnips.	*Clover* sown in half the barley ground.	Clover.	Wheat.

336. A piece of the cleanest wheat-stubble is sown with **trifolium**, which comes in as early green food in spring. Another piece is ploughed and prepared for **winter vetches**, which will be ready for use as soon as the trifolium is finished. If it be a clay loam, **cabbages** may be next planted on another patch of the fallow; or if in the less rainy parts of England, **mangels**. A considerable portion will be prepared for **swedes**; and the trifolium and vetch ground, or any other late-cleaned part of the fallow, will be sown in June with **late turnips**.

337. From this you will see that two crops—fodder and turnips—are obtained in one year off the same patch of the fallow.

338. Only **half the young barley**, which follows the fallow, is sown with **clover** for the next year; the other half being required for **beans**. When the rotation comes round again, the clover and beans will exchange places, and so they only come on the same ground once in eight years. There is no fear of clover or bean sickness under such a system. The beans will be hoed well when young; and the wheat that comes on the clover portion, will, if possible, be hoed also. By thus taking every opportunity of ridding his land of weeds, and having the fallow every fourth year, the farmer is able to grow a much larger quantity of sheep-keep on his fallow, than he would if he allowed it to get into a foul condition. Frequently, too, stubble-turnips or rape are drilled between the beans to furnish sheep-food after the beans are removed. Mustard also, as a 'catch crop,' is not unfrequently grown on the ground of the first corn crop that is carried.

339. This rotation under good management enables a farmer to grow a larger quantity of corn each year than the four-course system in its simplest form; and at the same time to grow a large quantity of wool and mutton. If none of the fodder crops fail, he has a continuous supply of sheep-keep throughout the year, without the aid of pasture-land. The first fodder crop of the year would be the trifolium; after which would come the vetches; the next crop would be the aftermath clover; and this would be followed by the mustard, rape, or stubble-turnips; and the stored mangels and swedes, the turnips in the field, and the hay from the first clover crop, would form a plentiful winter supply till trifolium was ready again in the spring. Still, a

little pasture is always particularly useful in case of failure of any of these crops, or in the event of one crop being finished before the next is quite ready.

340. A considerable quantity of oil-cake is frequently used in the fattening of the sheep, which yields a manure rich in nitrogen. So that all that is necessary by this rotation to thoroughly keep up the fertility of the soil, is the purchase of a moderate quantity of phosphate of lime for the root-crops.

THE END.

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